MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOLUME LV, PART 2.

THE GEOLOGY OF THE PART OF THE ATTOCK DISTRICT WEST OF LONGITUDE 72° 45′ E. BY G. DE P. COTTER, B.A., Sc.D. (DUBLIN), F.G.S., F.A.S.B., M.INST.M.M., M.INST.P.T., *Superintendent, Geological Survey of India.* (With Plates 11 to 19.)

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CHAPTER I.

INTRODUCTION.

General.

General description.

The Attock district is the most northerly of the districts of the Punjab, and is bounded on the west by the Indus river, on the north by the foot-hills of the Hazara Himalayas, on the east by Rawalpindi district, and on the south by the Salt Range, or by part of the Jhelum district. It takes its name from the famous fort of Attock, built by Akbar in 1581, which is on the banks of the Indus in the north-west corner of the district.

The district is divided into four tahsils, namely, Attock, Pindi Gheb, Fatehjang, and Talagang. The Attock tahsil, which is the most northerly, is separated by the Kala Chitta hills from the rest of the district. These hills, which run from east to west, commence as a narrow ridge on the borders of the Rawalpindi district, but broaden out near the boundary of the Fatehjang and Pindi Gheb tahsils, and continue to the Indus bank as a broad belt of hills up to eight miles in width. The highest peak is 3,481 feet above sea-level, and is three miles west of Choi bungalow and village, which is near the 21st milepost on the road from Campbellpur to Pindi Gheb.

Drainage.

The entire drainage of the district falls into the Indus. The northern portion of the district, north of the Kala Chitta, is drained mainly by the Haro river, which derives its waters from the Himalayan foothills between Abbottabad and Murree, and by the Nandna and Dhamruh tributaries of the Haro, the former of which rises east of Fatehjang, and traverses the eastern Kala Chitta by a gorge, joining the Haro south of Campbellpur, while the other and smaller tributary, passes Hasan Abdal to meet the Haro three miles west of that town.

The country south of the Kala Chitta is drained partly by the Resi stream which, after rising in the country between the Khair-i-Murat hill-range and the Kala Chitta, falls into the Indus below Khushhalgarh, and partly by the Soan river and its tributaries. This latter river rises in the Rawalpindi hills south of Murree, and passes from the Jhelum district along the boundaries of the Talagang and Pindi Gheb tahsils, finally reaching the Indus south of Makhad. The general slope of the Attock district is, therefore, towards the west and the Indus valley, but the Indus lies in a gorge from Attock to the gates of the Salt Range at Kalabagh. It is only in the neighbourhood of the Indus and the lower reaches of the Soan that the general level of the country falls below 1,000 feet above sea-level; the greater part of the district is between 1,500 and 2,000 feet above sea-level, while the south of the Talagang tahsil near the Salt Range rises to 2,300 feet. The Salt Range itself is not much above this height on the whole, but in certain tracts rises above 3,000 feet, and its highest point is Sakesar Hill, which is 4,992 feet above sea-level. Sakesar is the point where the three districts of Attock, Shahpur, and Mianwali meet.

From the above description it will be seen that the whole of the district is a plateau bounded on the south by the Salt Range and on the north by the Himalaya. This plateau, which extends eastward and south-eastward into Rawalpindi and Jhelum districts, is known as the Potwar plateau.

Hill-ranges : the Kala Chitta, Kawa Gar, and Kheramar hills.

It has been observed above that the district is divided into two by the Kala Chitta hills, which are the main hills of the district. These hills are in the main composed of black-weathering Murree sandstones, and white-coloured limestones of Eocene or Triassic age; the mixture of white and black rocks has given rise to the name of the black (*kala*) and white (*chitta*) hills.

Besides this main range, there are two minor hill-ranges north of the Kala Chitta, *viz.*, the Kawa Gar or Hill of Olives, a range about seven miles long south-east of Campbellpur, which derives its name from the abundance of *kao* or *kawa* (*Olea ferruginea*) or wild olive, and the Kheramar, which is about 6½ miles in length and lies south-west of Hasan Abdal.

The Kawa Gar is an unimposing range, the highest point of which is only 1,896 feet above sea-level. A dark-coloured Cretaceous shell limestone is well developed on this hill, and is worked into cups and vessels, which take a fine polish. Similar vessels have been dug up from the buried city of Taxila east of Hasan Abdal, and may be seen in the Taxila Museum.

The Kheramar takes its name from the rugged and rough surface of the hills, which are covered with limestone boulders and pebbles, making walking extremely tiresome and wearing to shoe-leather. It is this strain on footwear which the name implies, *khera-mar* meaning 'sandal-destroying'. The Kheramar rises to a height of 2,427 feet above sea-level. The range is continued through Hasan Abdal as a group of isolated hills separated from each other by an alluvial plain. There are some nine of these hills, of which the largest and highest is the Hasan Abdal Hill, which is 2,344 feet in height, with the shrine of the Panja Sahib at its top. At the western foot are the famous springs of Hasan Abdal, which issue from the limestone, and flow into the tank of Panja Sahib, in which sacred fish are kept, and which is surrounded by Sikh temples. To the north, an ancient tomb of one of Akbar's wives is known as Lala Rukh's tomb. South of the hill are the gardens and ruins of Wah, formerly a halting place of the Moghal emperors on their way to the Vale of Kashmir, and now better known for its cement works.

There are some hills of lesser importance north of the eastern termination of the Kala Chitta, and south and east of Bahtar village. The largest of these, one mile south of Bahtar, is the Chhibbiwali Gar, 1,966 feet in height.

Attock Hill.

Mention must also be made of the Attock Hill, 2,076 feet in height, which overlooks the fort of Attock and the Indus river. This historical hill and town has from time immemorial been a main halting place upon the road from Afghanistan to India. Attock lies on the east bank of the Indus at its junction with the Landai or Kabul river. It

was here that Alexander crossed by a bridge of boats, built by Hephaestion and Taxiles in 331 B.C. Until the opening of the railway bridge in 1883, a bridge of boats was maintained in the cold weather. Between the Kala Chitta and the Salt Range, the only hill-range of importance is the Khair-i-Murat range. About 20 miles long, it runs from the border of Rawalpindi district, through the southern half of Fatehjang tahsil, in a W. S. W. direction to Dhok Maiki village. Its greatest height is 3,104 feet. It separates the Fatehjang plain or *gheb* from the southward-sloping open country of the Soan valley. No other hills of importance occur in the Fatehjang, Pindi Gheb, and Talagang tahsils, until the Salt Range is reached on the southern margin of the district.

The Khair-i-Murat range.

From the above description, it is now clear that there are two main watersheds in the district, *viz.*, (1) the Kala Chitta, and (2) the Khair-i-Murat and the high ground to the west of its termination, which continues to near Makhad on the banks of the Indus. This divides the district into three drainage areas, *viz.*, the Haro valley to the north of the Kala Chitta ; the central plain or *gheb*, drained by the small Resi stream, and the broad Soan valley to the south.

There are no trees of large size in the district. The most luxuriant forest is to be found in the Kala Chitta, where acacias and wild olives abound. The largest trees are cultivated trees, and amongst these are the *shisham*, the mulberry, and the *banyan*. Occasionally the *kipal* and the *siris* (*Albizzia lebbek*) are grown.

Trees.

The open country of the Potwar, south of the Kala Chitta, is arid and bare ; in the parts where efflorescent salt (*kallar*) occurs, plants of a halophytic habit (*Salvadora*, etc.) occur, while on the sandstone hills a few thorny shrubs are all that relieve the bleak landscape.

The present geological survey of the Attock district is the work of myself, Mr. Harendra Mohan Lahiri, and Mr. Phanindra Nath Mukerjee, Extra Assistant Superintendents, Geological Survey of India. The work was begun in the early part of 1926 by Mr. Lahiri and myself, and in 1928 the party was strengthened by the addition of Mr. P. N. Mukerjee. With the exception of a very small area to the south-west, the survey of the district was completed in 1931.

Personnel of the Geological Survey party.

Prior to the present survey, the Attock district has frequently been visited by geologists, and the geology of the district has been already described by A. B. Wynne and others.

List of previous Literature.

The following is a list of papers dealing with the geology of the district, and of neighbouring areas :—

1832. Sir A. Burnes.—Some Account of the Salt Mines of the Punjab. *Journ. As. Soc. Beng.*, I, p. 145.

1833. Sir A. Burnes.—On the Geology of the Banks of the Indus. *Geol. Trans.*, S. r. II, III, p. 491.

1834. W. Pottinger.—On the Present State of the River Indus, and the Route of Alexander the Great. *Journ. Roy. As. Soc.*, I, p. 199.

1839. G. T. Vigne.—Outline of a Route through the Panjab, Kabul, Kashmir, and into little Tibet. *Journ. Roy. Geogr. Soc.*, IX, p. 512.

1851. N. Vicary.—On the Geology of the Upper Punjaub and Peshaur. *Quart. Journ. Geol. Soc.*, VII, Pt. 1, p. 38.

1853. A. Fleming.—On the Salt Range of the Punjaub. *Quart. Journ. Geol. Soc.*, IX, Pt. 1, p. 189.

1854. A. Cunningham.—Ladakh, Physical, Statistical, and Historical, with notices of the surrounding countries. London.

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1874 to 1887. R. Lydekker and R. B. Foote.—Indian Tertiary and Post-Tertiary Vertebrata. *Pal. Ind.*, Series X, Vols. I, II, III, and IV.

1874. A. B. Wynne.—Notes on the Geology of the neighbourhood of Mari (Murree) Hill-Station in the Punjab. *Rec. Geol. Surv. Ind.*, VII, p. 64.

1875. A. B. Wynne.—The Trans-Indus Salt Region in the Kohat district. *Mem. Geol. Surv. Ind.*, XI, p. 105.

1877. A. B. Wynne.—Note on the Tertiary Zone and Underlying Rocks in the North-West Punjab. *Rec. Geol. Surv. Ind.*, X, p. 107.

1877. W. Theobald.—On the occurrence of Erratics in the Potwar. *Rec. Geol. Surv. Ind.*, X, p. 140.

1877. W. Theobald.—Remarks critical and explanatory, on some statements in Mr. Wynne's paper on the Tertiaries of the North-West Punjab. *Rec. Geol. Surv. Ind.*, X, p. 223.

1878. A. B. Wynne.—What is an Erratic ? *Geol. Mag.*, V, p. 185.

1878. W. Theobald.—What is an Erratic ? *Geol. Mag.*, V, p. 333.

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1879. W. Theobald.—On a marginal bone of an undescribed tortoise from the Upper Siwaliks, near Nila, in the Potwar, Punjab. *Rec. Geol. Surv. Ind.*, XII, p. 186.

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1880. A. B. Wynne.—On the Trans-Indus Extension of the Punjab Salt Range. *Mem. Geol. Surv. Ind.*, XVII, p. 211.

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1910. T. H. D. La Touche.—Lakes of the Salt Range in the Punjab. *Rec. Geol. Surv. Ind.*, XL, p. 36.

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1921. A. Preiswerk.—Geological Features of the Oil Region in North-West Punjab. *Geol. Mag.*, pp. 3, 74, 124.

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1925. W. F. L. Nuttall.—Indian Reticulate Nummulites. *Ann. & Mag. Nat. Hist.*, Ser. 9, XV, p. 661.

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1926. L. M. Davies.—Notes on the Geology of Kohat. *Journ. As. Soc. Beng.*, New Ser., XX, p. 207.

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1926. G. E. Pilgrim.—The Tertiary Formations of India. *Proc. Pan-Pacific Sci. Congress*, 1923, p. 896.

1926. D. N. Wadia and L. M. Davies.—Note on gypsified marl and Alveolina Limestone in the Gypsum Zone of Bahadur Khel. (*As. Soc. Beng.*), *Proc. Thirteenth Ind. Sci. Congress*, p. 255.

1927. G. de P. Cotter.—The Distribution of the Gault in India. *Rec. Geol. Surv. Ind.*, LIX, p. 405.

1927. L. M. Davies.—Supplement to 'Notes on the Correlation of Pinfold's Chharat Series'. *Trans. Min. Geol. Inst. Ind.*, XXI, p. 313.

1928. R. van V. Anderson.—Tertiary Stratigraphy and Orogeny of the Northern Punjab. *Bull. Geol. Soc. Amer.*, XXXVIII, p. 665.

1928. D. N. Wadia.—The Geology of Poonch State. *Mem. Geol. Surv. Ind.*, LI, Pt. 2.

1928. J. M. Weller.—The Cenozoic History of the North-West Punjab. *Journ. Geol.*, XXXVI, p. 362.

1929. G. de P. Cotter.—The Erratics of the Punjab. *Rec. Geol. Surv. Ind.*, LXI, p. 327.

1929. A. L. Coulson.—The North-West Himalayan Earthquake of 1st February 1929. *Rec. Geol. Surv. Ind.*, LXI, p. 279.

1929. W. D. Matthew.—Critical Observations upon Siwalik Mammals. *Bull. Am. Mus. Nat. Hist.*, LVI, p. 437.

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1930. G. Benson-Cooke.—Oil Occurrences in the North-West Punjab. *Petrol. Times*, XXIV, p. 613.

1930. L. R. Cox.—The Fossil Fauna of the Samana Range. Lower Albian Gastropoda and Lamellibranchiata. *Pal. Ind.* New Ser., Vol. XV, Pt. IV.

1930. H. M. Lahiri.—On a small Dome near Mari in Attock District. *Rec. Geol. Surv. Ind.*, LXIII, p. 279.

1930. L. F. Spath.—The Fossil Fauna of the Samana Range. The Lower Cretaceous Ammonoidea. *Pal. Ind.*, New Ser., Vol. XV, Pt. V.

1930. A. L. Coulson.—Second Note on the North-West Himalayan Earthquake of the 1st February, 1929. *Rec. Geol. Surv. Ind.*, LXIII, p. 434.

1931. L. R. Cox.—A Contribution to the Molluscan Fauna of the Laki and Basal Khirthar Groups of the Indian Eocene. *Trans. R. Soc. Edinb.*, LVII, Pt. I, (No. 2).

Maps.

Field work.

Field work was done on the maps of the Survey of India on the scale of one inch to one mile, and afterwards the work was reduced to the scale of one quarter-inch to the mile for reproduction in Plate 19. In the Kala Chitta hills, some old forest maps, now out of print, on a scale of four inches to the mile, were found extremely useful; for the mapping

of the Kala Chitta had to be done in greater detail than in the open plateau country to the south, owing to the greater complexity of the geology. Where these forest maps were not available, use was made of other forest maps on a scale of two inches to the mile.

Spelling.

The spelling adopted in this memoir is that of the Survey of India maps. An index of villages and localities mentioned is incorporated in the general index, together with the latitude and longitude, whereby the position of each place can be ascertained on the geological map, Plate 19.

Previous geological maps.

Of previous geological maps of this district, that published in 1877 by A. B. Wynne (in *Rec. Geol. Surv. Ind.*, X, Plate at p. 107) is on too small a scale (eight miles to the inch) and the topographical details are too sketchy, so that it has not been of much use. Certain portions of the district, *viz.*, the Chinji area, the Chak Dalla area in the Kala Chitta, the Chharat anticline, and the Khaur dome, have been mapped by Sir E. H. Pascoe and Mr. E. S. Pinfold, and the maps have been published in *Mem. Geol. Surv. Ind.*, XL, Part 3. With the exception of these maps, the area now under report represents original maps by Messrs. H. M. Lahiri, P. N. Mukerjee and myself.

CHAPTER II.

PRE-TERTIARY FORMATIONS.

List of formations.

The formations met with (omitting the Attock slates and the Salt Range suite of Palæozoic and older rocks, which last are not found in Attock district) are entirely Triassic or newer rocks. The following is a table of formations in descending order :—

Formation.	Age.
Low-level alluvium	Recent.
Older and high-level alluvium : moraine material near Jassian ; erratic blocks ; boulder beds, conglomerates, and travertine.	Sub-Recent.
Upper Siwaliks, (in Jhelum district only), Tatrot zone	Middle Pliocene.
Middle Siwaliks—	
Bhandar beds not recognised.	
Dhok Pathan beds	Lower Pliocene.
Nagri beds	Pontian.
Lower Siwaliks—	
Chinji beds	Sarmatian.
Kamlial beds (included in the Murree series in this memoir, but previously in Siwaliks).	Tortonian.
Upper Murrees (excluding Kamlials)	Helvetian to Tortonian.
Lower Murrees (excluding basal beds ' Fatehjang zone ')	Helvetian.
Lower Murrees (Fatehjang zone)	Burdigalian.
(*Unconformity represented by basal conglomerate, without discordance, age Priabonian to Aquitanian.*)	
Chharat series—	
Upper Chharats—	
(*b*) Nummulitic Shale	Middle Khirthar or Lutetian.
(*a*) Shales, marls and limestones with fragmentary shells.	Lower Khirthar or Lutetian.
Lower Chharats—	
Red and green shales, red sandstones, thin limestones, bleached marls.	Laki or Ypresian.
Lower Nummulitic or Hill Limestone	Ypresian.
Ferruginous Pisolite	Probably basal Laki.
Shales north of Kawa Gar	Uncertain, perhaps Ranikot.
Giumal limestones, sandstones and sandy limestones	Albian.
Spiti shales	Argovian to Tithonian.
Kioto limestone	Upper Triassic to Liassic.
(*Unconformity.*)	
Attock slates	Pre-Cambrian probably.

It will be convenient to discuss these formations in an order reverse to that given in the above table, that is, commencing with the oldest.

The Attock Slates.

Attock slates: outcrops in the Attock district.

In the Attock district, the Attock slates are exposed in an outcrop, 5½ miles long and four miles broad between Attock town and Haji Shah village. Besides this main outcrop, there are two small outcrops south of Kamra village, seven miles N. N. E. of Campbellpur. The slates are again seen in some hills three miles north of Burhan, but these hills are geographically part of the Hazara Himalaya. The hills just enter into the Attock district, and then sink under alluvium. The northern (Hazara) extension of these hills has been mapped by C. S. Middlemiss[1] as Hazara slate series, and there is no doubt that the Hazara slate and the Attock slate are identical.

Stratigraphical relationships of the slates in Hazara.

In the Attock district, the occurrences of Attock slate are separated from the Kala Chitta suite of rocks by a broad belt of alluvium, and their stratigraphical relationships are therefore only apparent from inferences derived from sections in other areas. The outcrop at Attock is continued across the Indus into the Peshawar district, but the geology of Peshawar has not yet been worked out. The geology of the Hazara district is however well known from C. S. Middlemiss' memoir above quoted, six miles south of Abbottabad, the Attock or Hazara slates are overlain by the Infra-Trias series with the Tanakki boulder bed at its base. In the country east of Abbottabad, and also in the country about 14 miles south of Abbottabad, the so-called Trias, or more accurately speaking, the Kioto limestone, rests directly upon the Attock slates, without the interposition of the Infra-Trias. From these observations it may be inferred that in the country which is geologically on the strike of the Kala Chitta hills and to the E. N. E. of these hills, the Infra-Trias is not developed, and the Kioto limestone rests directly upon the Attock slate. Further, it is clear from the section near Tanakki about six miles south of Abbottabad, that the Attock slate is considerably older than the basal boulder bed of the Infra-Trias, which last (*vide infra*) is homo-

[1] Map accompanying *Mem. Geol. Surv. Ind.*, XXVI, (1896).

taxial with the Talchir boulder bed. The Attock slates are therefore pre-Talchir in age, that is, older than Upper Carboniferous.[1]

Relationships with the Tanawals.

To say that the Attock slates are older than Upper Carboniferous is perhaps to insist upon what was already obvious. But the arguments for a pre-Cambrian age rest upon reasoning of rather more speculative nature. In Hazara, A. B. Wynne[2] found a quartzite series to which he gave the name Tanol, or (spelt more accurately) Tanawal. The stratigraphical relationships of these Tanawals are discussed by Middlemiss (*op. cit.*, pp. 56, 237), and although they are doubtful, Middlemiss thinks that in part at least they underlie the Infra-Trias. Similar beds in Poonch were mapped by D. N. Wadia, who at first[3] regarded them doubtfully as of Gondwana age. He afterwards[4] came to the conclusion that some of these rocks belonged to the older Palæozoics, and in consultation with W. D. West[5] he correlates the lower part of the Tanawals with the Jaunsar series of Simla, with a Lower Palæozoic age. Now it is generally admitted by these geologists that the Dogra slate of Kashmir and the Hazara slate underlie these Tanawals, and it is also believed by W. D. West that the Simla slate underlies the Jaunsar series. These two geologists therefore correlate the Simla slate, the Dogra slate and the Attock or Hazara slate, and regard the age as possibly Cambrian or pre-Cambrian. This view is not new, but was originally advocated by Middlemiss (*op. cit.*, p. 15), but the recent work of Messrs. Wadia and West has strengthened our belief in the age assigned to the Attock slates.

Structure and lithology.

The Attock slates near Attock have a strike more or less E.-W. The small Kamra outcrop strikes to east by south. In the country north of Burhan, the slates in the foothills of the Hazara Himalaya strike to north-east by east. Thus the strike veers round to the

[1] C. S. Middlemiss (*Mem. Geol. Surv. Ind.*, XXVI, p. 19) agrees with a suggestion first made by R. D. Oldham (Manual of Geology of India, 2nd edn., p. 138) that the basal Infra-Trias boulder bed at Tanakki is homotaxial with the Talchir boulder bed. D. N. Wadia (*Rec. Geol. Surv. Ind.*, LXII, p. 152) reports the occurrence of glaciated boulders in the Tanakki boulder bed. Subsequently (*Rec. Geol. Surv. Ind.*, LXIII, p. 130) he found that the Infra-Trias basal conglomerates were interbedded with Agglomeratic Slate in North Hazara. The age of the Agglomeratic Slate is known to be from Middle to Upper Carboniferous (*Pal. Ind.*, N. S., Vol. XII), therefore the Tanakki boulder bed is not newer than Upper Carboniferous and is undoubtedly homotaxial with the Talchir boulder bed as Middlemiss and Oldham suggested.

[2] *Rec. Geol. Surv. Ind.*, XII, p. 122, (1879).

[3] *Mem. Geol. Surv. Ind.*, LI, Pt. 2, 244, (1928).

[4] *Rec. Geol. Surv. Ind.*, LXIII, pp. 131, 132, (1930).

[5] *Rec. Geol. Surv. Ind.*, LV, p. 128, (1931).

north-east as one passes from Attock to Burhan. This curve in the strike is due to the commencement of the great Hazara syntaxis described by D. N. Wadia,[1] and by previous observers.

The dips in the Attock slate tend to be vertical, or swing on either side of the vertical at angles of 60 or 70 degrees of dip.

The Attock slate is bluish grey to bluish black in colour, easily fissile, much crushed and jointed, and never suitable for roofing slates. Although generally homogeneous, it occasionally contains gritty layers of an arenaceous type, although in the Attock outcrop never a true sandstone. In the Attock outcrop, there are no signs of metamorphism. In the foothills of the Hazara Himalaya north of Burhan, there is to the north-west, a slight development of phyllitic structure, quartz-veins are very common, and pressure-wrinkles are frequent. Near Jhamra, $5\frac{1}{2}$ miles N. N. E. of Burhan, micaceous sandstones and arenaceous slates are associated with the more typical slates, and the facies is more arenaceous than in the hills near Attock. The Attock slates are everywhere unfossiliferous.

Unconformity above the slates.

It has been suggested above that the unconformity between the Attock slate and the Kioto limestone represents the absence of the whole of the Palæozoic (with perhaps the exception of the Cambrian, if indeed the Attock slates are as new as Cambrian), and it is also probable that the Lower and Middle Trias (Lilang system) is missing.

The Kioto Limestone.

Kioto limestone: 'Triassic' limestone of former authors.

The Triassic Limestone, as it has been called in former descriptions of the geology of Attock and Hazara, was first described in Sirban Hill overlooking Abbottabad by Waagen and Wynne,[2] who found *Megalodon* and *Dicerocardium*, together with *Chemnitzia*, *Gervillia*, *Rhynconellae*, and *Terebratulae*, indicating an Upper Triassic age, and corresponding with the Para stage of the Kioto limestone of Spiti. Many specimens of rock with comminuted shells have been found in the 'Triassic' limestone of Attock, but as a rule, none have been identified. But a small collection was made in the

Fossil contents.

railway cutting between Campbellpur and Jhalar in the north margin of the Kala Chitta hills

[1] *Rec. Geol. Surv. Ind.*, LXV, p. 189, (1931).
[2] *Mem. Geol. Surv. Ind.*, IX, Pt. 3, (1872).

by Mr. N. Aiyengar, Field Collector, Geological Survey of India. Another collection from Garhiala village in the western part of the Kala Chitta was made by Mr. Lahiri. These collections were sent to the British Museum (Natural History), for examination. The results have not yet reached Calcutta, but Mr. L. R. Cox informed me that amongst the specimens was a species that appeared to be identical with the Liassic *Velata velata* (Goldfuss). Mr. Cox thinks that the limestone is here Liassic. If that is the case, it appears that the limestone ranges from Upper Triassic to Liassic. It would thus correspond exactly with the Kioto limestone of Spiti.

Correlation with Kioto limestone of Spiti.

The name Kioto limestone was employed by Sir Henry Hayden[1] for a great limestone formation over 2,000 feet thick, and sparsely fossiliferous, which is developed in Spiti and other parts of the north-western Himalaya. F. Stoliczka[2] had previously designated the lower part of this limestone the Para limestone, and the upper part the Tagling limestone, but Sir H. H. Hayden points out that the limestone is a single stratigraphical unit and cannot be thus divided in the field. The uppermost beds contain, near Giumal village in Spiti, the Callovian *Erymnoceras coronatum*,[3] and in the Shalshal cliff, in the Girthi valley in north Almora district, the Kioto limestone is capped by six feet of red pisolite known as the '*Sulcacutus*' beds,[4] from the presence of a belemnite belonging to the group of *bisulcati* and associated with *Sphaeroceras* and *Macrocephalites*. The horizon was believed by C. Diener to represent the Callovian.

Kioto limestone of Hazara and Kashmir.

Above the Kioto limestone is found in Spiti, Byans, etc., the Spiti shales, which range from Argovian with *Epimayites*, *Prograyiceras*, etc., to Valanginian with *Neocomites neocomensis*. These same Spiti shales are found overlying the so-called Triassic Limestone both in Hazara and in Attock. It now becomes quite clear both from the contained fossils and from the stratigraphical position of the limestone and from its distinctive lithological character, that the Kioto limestone of Spiti, Painkhanda, and Byans is identical with the so-called Triassic Limestone of Hazara and of Attock. Both are massive limestones sparsely fossiliferous. In Kashmir,

[1] 'Geography and Geology of the Himalaya', Pt. IV, p. 236, (1907).
[2] *Mem. Geol. Surv. Ind.*, V, pp. 62, 66, (1865).
[3] *Mem. Geol. Surv. Ind.*, XXXVI, Pt. 3, p. 101, (1912).
[4] *See Mem. Geol. Surv. Ind.*, XXIII, p. 137, (1891) and *Denks. kais. Akad. Wissensch. Wien*, LXII, p. 584, (1895).

the Para stage is represented by limestone with *Dicerocardium himalayense*, and *Megalodon ladakhensis*, and *M. cultridens*,[1] which indicate a horizon equivalent to that at Sirban Hill (*vide supra*), and which is regarded as Noric by C. Diener[2]. The Kioto limestone therefore ranges from Upper Trias to basal Oolitic, and embraces the whole of the Lias. It occurs from the Kumaon Himalaya through Spiti and Kashmir to Hazara and Attock district. In Hazara, the thickness of the limestone is given as from 500 to 1,200 feet. It is there underlain by 50 to 100 feet of volcanic material, hematite-breccia, quartzites, and shales. The volcanic rocks may perhaps be correlated with the Panjal trap of Kashmir, which has been shown by C. S. Middlemiss[3] to range upwards to the Upper Trias. It is important to note that no rocks resembling the Lilang system (Lower to Middle Trias) of Spiti and Kashmir nor the Ceratite Limestone of the Salt Range (Lower Trias) occur either in Hazara or in Attock.

Thickness of Kiotos in Kala Chitta.

Owing to the complicated structure of the Kala Chitta, and the prevalence of strike faults, inversion, and reduplication, the thickness of the Kioto limestone of Attock is not to be accurately estimated, but in the west of the Kala Chitta, Mr. Lahiri's sections (Pl. 15, figs. 9 and 10) point to a thickness of 1,600 feet. The base is nowhere seen. The Kioto limestone occurs in the cores of anticlines in the Kala Chitta, the strike is generally east to west, and the dips are usually steep, or, when gentle, the structure is recumbent.

Mr. H. M. Lahiri found the following fossils in the Kioto limestone near Garhiala village :—

Pecten sp.
Lima serraticosta, Bittner.
Terebratula sp.

Lima serraticosta characterises the Noric of Spiti and Painkhanda,[4] and its presence here indicates the presence of the Para stage of the Kioto limestone.

Lithology.

The Kioto limestone of Attock district is a grey limestone with lavender, pink, and yellow patches, mottles or bands. The texture is finer than that of the Laki or Hill Limestone above, and the fracture surfaces

[1] *Pal. Ind.*, Ser. XV, Vol. 3, pp. 62, 65, (1899).
[2] *Mem. Geol. Surv. Ind.*, XXXVI, Pt. 3, p. 115, (1912).
[3] *Rec. Geol. Surv. Ind.*, XLIII, p. 38, (1913).
[4] *Mem. Geol. Surv. Ind.*, XXXVI, Pt. 3, pp. 94-99, (1912).

are smooth and generally curved. The grey limestone is a dull drab grey and contrasts with the blue-grey limestone of the Laki or Hill Limestone, but bluish limestone does occur in the Kioto series. Occasionally, fragments of shells, generally lamellibranchs, occur, but they are so broken as to be unidentifiable. The limestone is well bedded, and sometimes banded, due to the alternation of yellow and grey bands. Crystalline calcite is not uncommon. The weathered surface has a pitted or grooved appearance.

Ferruginous beds in the Kiotos.

Ferruginous shales and bleached shales were noticed by Mr. Lahiri in a *nala* section $1\frac{1}{2}$ miles E. S. E. of Bagh Nilab village. The same observer notes the occurrence of thin purple shales in the Kiotos, about $1\frac{1}{2}$ miles south-west of Choi. Marls and ferruginous shales are well exposed in the railway section south of Campbellpur, where the railway enters the Kala Chitta. The exact spot is the cutting just north of the most northerly tunnel. About 300 feet of marls and ferruginous shales are exposed. Fossils occur, but generally these are broken. As noticed above, a collection made by Mr. N. Aiyengar is being examined in London. Similar red ferruginous beds are seen north of Ganji Bhal camping-ground, and also halfway up the slopes of Hindu Mar Magar Hill. In the low hills east of Campbellpur, there are red beds in the Kiotos north of Mirza, and again north of Kawah. In the Kheramar hills, red beds and soft marls occur in the Kiotos south and south-west of peak 2,427.

It is difficult to be certain of the stratigraphical position in the Kiotos of these red beds. My general impression is that they do not hold a very low position. It would be tempting to compare them to the basal division of the Kiotos of Hazara, which consist of volcanic material, haematite-breccia, quartzites and shales. But there is in the Attock district no trace of volcanic material associated with these red beds, and experience has taught me that lithological correlations, not backed by palæontological or stratigraphical evidence, are more plausible than sound. In the Himalaya, the '*Sulcacutus*' beds, which cap the Kioto limestone are ferruginous pisolite. The exact horizon of the red beds and marls in the Kiotos of the Kala Chitta must be left undecided. Sir Edwin Pascoe[1] considers that the thickness of the Kioto limestone in the Chak Dalla area does not exceed 800 feet.

[1] *Mem. Geol. Surv. Ind.*, XL, p. 384, (1920).

The Spiti Shales.

Spiti shales: cannot be mapped separately from Giumals.

That the Spiti shale horizon exists in the Kala Chitta is certain from the occurrence of ammonites of Spiti shale age. It has not, however, been possible to map the Spiti shales as a separate unit from the Giumals above. In the west of the Kala Chitta, near the Indus two sections were worked out by Mr. Lahiri, *viz.*, (1) a section in the *nala* one mile north-west of Bata village, and (2) a section on the hill-slopes one mile north of Ghora Mar village.

In section (1), the base of the section shows 160 feet of soft sandy and carbonaceous shales. In the second section, there are 200 feet of soft shaly and carbonaceous belemnite-bearing beds and yellow and olive clays. It is thought that these carbonaceous, sandy and yellow shales and clays are of Spiti shale age, and that the upper portion of the sandstones shales and limestones above are of Giumal age.

Thickness.

The total thickness of the Giumals and Spiti shales together does not exceed 320 feet, and is usually less. As a rule, the series is sheared, and attenuated, and frequently occurs as isoclinally squeezed bands in the Kioto or Nummulitic Limestone; the disturbance and shearing render continuous mapping of beds so difficult and necessitate work so detailed and on so large a scale as to be impracticable for a Geological Survey that has to consider the financial cost. Apart from the disturbance, there is no doubt that the whole series is highly condensed, and that the determination of the different stages would present great difficulty. The condensed character of the Giumals in Kohat has been commented on by Dr. L. F. Spath.[1] Fossils are not to be found, except in favoured localities, so that the palæontology is only of limited help.

Succession obscured by shearing.

Fossils and age.

The examination of the ammonites is in the hands of Dr. Spath. He has informed me that amongst the ammonites sent to him from these beds, the species *Mayaites maya*, *Peltoceratoides* sp. and *Perisphinctes virgulatus* indicate beds ranging from Argovian to Kimmeridgian. *Spiticeras* and *Himalayites* represent the Tithonian; the Hauterivian to Aptian is not represented by any ammonites, but the Gault is

[1] *Pal. Ind.*, N. S., Vol. XV, Pt. V, p. 52, (1930).

represented by *Oxytropidoceras*. This last comes clearly not from the Spiti shale horizons, but from the Giumals proper. It is perhaps desirable to give a brief description of the Spiti shales in other localities. The type area is of course Spiti, where the shales overlie the Kioto limestone and underlie the Giumal sandstone. They are in Spiti about 500 feet thick, and contain an ammonite fauna described by V. Uhlig.[1] These ammonites indicate a range from Argovian to Valanginian. The basal beds contain *Epimayites lemoini*, *Prograyiceras grayi*, and *Belemnopsis gerardi*. This fauna may be taken as equivalent to the Kantkot sandstone of Kachh, that is, Argovian to Kimmeridgian. The Middle Spiti shales or Chidamu beds, range from Kimmeridgian with *Hildoglochiceras latistrigatum*, *Aulacosphinctoides rotundidoma*, to Tithonian with *Virgatosphinctes densiplicatus*, and *V. Oppeli*. The Upper Spiti shales or Lochambel beds contain *Spiticeras*, *Himalayites*, *Astieria*, *Acanthodiscus*, *Neocomites*, indicating an age ranging from upper Tithonian to Valanginian. The Valanginian zone fossil *Neocomites neocomensis* occurs both in the Lochambel beds and in the Salt Range,[2] at Daoud Khel. At Thal in the Kohat district, the Gault or Giumal beds are underlain by Valanginian or Lower Hauterivian strata with *Olcostephanus* aff. *asterianus*.[3] It would appear that so far, there is no evidence of Upper Hauterivian or Barremian strata in North-West India, but further work is necessary before we can be certain that there is a stratigraphical gap between the Spiti shales and the Giumals representing the Upper Hauterivian and Barremian. It may be noted, however, that in Kachh, the Tithonian or Lower Umia beds, are separated from the Upper Aptian or Upper Umia beds of Ukra hill by plant beds possibly of Hauterivian and Barremian age, and perhaps corresponding to the probable stratigraphical gap.

Spiti shales of Spiti.

Correlation with similar beds in Salt Range and Kohat.

In Hazara, the Spiti shales and Giumals are described by C. S. Middlemiss,[4] who gives a total thickness of 200 feet for the whole series. The Spiti shales are characteristic of the northern part of his map, while in the south, in a thickness of 300 feet, there are

Spiti shales and Giumals of Hazara.

[1] *Pal. Ind.*, Ser. XV, Vol. IV, (1903).
[2] *Central blatt für Min.*, pp. 439-448, (1903).
[3] *Pal. Ind.*, N. S., Vol. XV, Pt. V, p. 58, (1930).
[4] *Op. cit.*, pp. 30-38.

only ten to 15 feet of black shaly sandstone and black shale. The upper horizons are mainly shaly limestone, shell limestone, and sandstone. The facies of the series has changed to a calcareous type, while the shales have thinned out, if, as seems probable, the ten to 15 feet of black shale and sandstone at the base are all that are left.

C. S. Middlemiss refers the Giumals and the Spiti shales of Hazara to the Jurassic, and marks as Cretaceous a thin capping bed six to ten feet thick, which is rich in ammonites. This will be discussed under the head of Giumal limestone and sandstone; meanwhile, it is sufficient to observe that, possibly, beds of Jurassic age are to be found only in the basal black shales of the series. The shell limestone is compacted of undeterminable species of *Ostraea*, while the sandstone contains *Trigoniae* of the same type as is found in the Uitenhage beds of South Africa and in the Umia beds of Kachh (*T. ventricosa*, *T. smeei*). The age of these is possibly basal Cretaceous (Valanginian) rather than Tithonian, but this is uncertain. As, however, the Spiti shales of Spiti stride upwards through the Jurassic into the basal Cretaceous (Valanginian), it is not necessary to regard the shell limestones and sandstones of Attock and of Hazara as belonging to a higher horizon than the Upper Spiti shales. The Giumals of the type area in Spiti have been worked out palæontologically by A. Spitz,[1] whose results have been revised by L. F. Spath.[2] L. F. Spath regards the '*Stoliczkaia dispar*' as a fragment possibly of an Aptian *Dufrenoia*; also the *Parahoplites*, figured by Spitz, may in Spath's opinion be a lower Albian acanthoplitid, while the *Astieria* is indicative of an Upper Valanginian age. The age of the Giumals then appears to range from Upper Valanginian to Albian, and there is no longer any evidence of Cenomanian strata in the Giumals. At the same time, the Giumals are brought much nearer in age to the Spiti shales, than was formerly supposed. If, however, we could regard the *Astieria*, the locality of which is doubtful, as coming from the Spiti shales, and having been included in the Giumal fauna by mistake, we might regard the Giumals of Spiti as wholly later in age than the Spiti shales. If, however, it really comes from Giumal sandstone, there may be some lateral change of facies which causes the Upper

Corrections to Spitz' determinations.

[1] *Rec. Geol. Surv. Ind.*, XLIV, p. 197, (1914).
[2] *Pal. Ind.*, New Ser., Vol. XV, Pt. V, p. 59, (1930).

Spiti shale (Lochambel beds) to show the same fauna as the basal Giumals in other sections. In any case, we are not in a position to say that the Hauterivian is absent in Spiti, since the fauna is too scanty, but the ammonites (apart from the *Astieria*) indicate Aptian and Albian, and the Cenomanian is absent, that is, the correspondence with the Albian of Hazara and of the Samana Range is complete. The only doubtful question is where we should draw the line between the Giumals and the Spiti shales; this question however need not trouble us here, since the Spiti shales and the Giumals of Attock have been mapped as one stratigraphical unit. Mr. Lahiri notes that the uppermost bed of Kioto limestone, underlying the Spiti shale-Giumal unit, has a lateritic appearance. Perhaps a comparison may be made with the ferruginous pisolite of the Callovian '*Sulcacutus*' beds of Kumaon.

Giumal Limestones, Sandstones, and Sandy Limestones.

So much has been said regarding the Giumals in the preceding section describing the Spiti shales that the present account can be made brief. Mention has been made in the beginning of the preceding chapter of two sections through the Spiti shale-Giumal unit, which were worked out by Mr. Lahiri. They are as follows:—

Sections in western Kala Chitta.

A. Section in *nala* about one mile north-west of Bata.	Feet.	B. Section on hill-slope one mile north of Ghore Mar.	Feet.
6. Thick marly limestone, ochreous and with fossiliferous layers near base	27	7. Unfossiliferous, ochreous limestone or sandy limestone, usually yellow, sometimes tinged with red . . .	8
		6. Hardened calcareous clay, (unfossiliferous) . .	10
5. Earthy shale with partings of hardened, fossiliferous, calcareous clay, the shale becoming sandy downwards . .	50	5. Well-bedded, marly limestone or calcareous clay with occasional thin fossiliferous layers	40
4. Greenish or olive, well-bedded, soft, unfossiliferous sandstone	27	4. Soft, greenish sandstone with occasional fossiliferous layers	40
3. Same unfossiliferous sandstone as above, but a little harder .	38	3. Massive olive unfossiliferous sandstone . . .	7

(*Descending order.*)

A. Section in *nala* about one mile north-west of Bata—(*contd.*)		B. Section on hill slope one mile north of Ghore Mar—(*contd.*)	

(*Descending order.*)

	Feet.		Feet.
2. Brown, calcareous sandstone or sandy limestone with markings of large and small shells. Quartz grains standing on weathered surfaces . .	5	2. Massive, rather compact ochreous limestone with frequent markings of large and small lamellibranch shells .	15
1. Beds, ill seen, apparently soft, sandy and carbonaceous shales; carbonaceous shales seen towards base . .	160	1. Soft, shaly beds, olive or yellow clays and carbonaceous shales with Belemnites near base . . .	200
TOTAL .	307	TOTAL .	320

In the above sections, so far, it appears certain that the lowest bed is both lithologically and by its fossil contents of Spiti shale age, while the uppermost beds must be Gault by reason of the occurrence of *Oxytropidoceras*. The age of the intervening beds is as yet doubtful, but if the shell limestone of bed 2 is the same as that described by C. S. Middlemiss in Hazara,[1] which yielded *Trigoniae* (*T. ventricosa* and *T. smeei*), it may be of Valanginian or Upper Spiti shale (Lochambel beds) age. It is not possible to state the age of beds 3 to 5, but Mr. Lahiri and I regard the top bed as Albian, and we are unable to draw any line between the Spiti shale division and the Giumal division.

Fossils.

Section in Hazara.

The section described by C. S. Middlemiss in Hazara, mentioned above, is as follows:—

(*Descending order.*)

	Feet.
6. Ferruginous pisolite (? Laki)	1
5. Buff coloured, thin bedded, shelly limestone	100
passing into	
4. Compacted, massive, shelly limestone	50
passing into and alternating with	
3. Alternations of Giumal sandstone and compacted, shelly limestone	60
2. Giumal sandstone with thin calcareous beds of *Trigoniae* .	80
1. Black, shelly sandstone and black shales	10-15

[1] *Op. cit.*, p. 32.

In this section, bed 1 obviously corresponds with the black shales at the base of the sections in Attock district. Bed 2 may correspond with bed 2 of Attock district; it is apparently called Giumal rather than Spiti shale series by reason of its lithological character, but the *Trigoniæ* may indicate a Lochambel age.

In the slate zone of Hazara and the northern part of the Nummulitic zone, the section is very different. Here the Giumal-Spiti series falls into two subdivisions only, *viz.*—

2. Giumal sandstone *passing downwards by gradual passage into*	Total thickness of 1 and 2 is 30 to 200 ft.
1. Spiti shales	

It will be noticed that the limestone so typical of southern Hazara and Attock district is absent. But in those parts of Hazara where the facies is simply shale succeeded by sandstone, this passes up into a sandy limestone rich in fossils and only six to ten feet thick. This rock is generally of a bright orange colour. C. S. Middlemiss obtained from it a good collection of ammonites, which he regarded as Cenomanian in age. In 1917, I was engaged with Mr. B. B. Gupta in revising the palæontological show-cases and collections in the Indian Museum. On examining the Hazara ammonites, we both came to the conclusion that the age was Gault and not Cenomanian.[1] The Hazara ammonites from the so-called Cenomanian were subsequently described by Dr. L. F. Spath.[2] *Oxytropidoceras* which was found in the Attock district is also common in Hazara. With it occurs *Douvilleiceras*, *Lyelliceras*, and other genera. The fauna is mainly Middle Albian, but in two localities it is Upper Albian. In the Samana range of Kohat, twelve forms are described of which eleven are Middle Albian and one Upper Albian. Thus there is a close correspondence between the Gault or Giumals of Hazara, Attock and Kohat. Moreover, the Kohat beds in the Samana range are underlain with beds of Valanginian or Lower Hauterivian age with *Olcostephanus* aff. *astierianus*. As beds of the same age occur in the Spiti area the correspondence with the Giumals of Spiti is exact, provided we exclude the Valanginian from the Giumals, and refer it to the Upper Spiti shale group.

Age.

Comparison with Spiti area.

[1] *See* Cotter, 'The Distribution of the Gault in India', *Rec. Geol. Surv. Ind.*, LIX, p. 405, (1926).

[2] *Pal. Ind.*, N. S., Vol. XV, Pt. V.

Dr. Spath points out that the so-called Cenomanian mentioned by H. G. Seeley[1] in the Sakesar mountain of the Salt Range and by E. Koken in the Samana range,[2] is not existant. The Samana range fossils are Gault in age. The fossiliferous horizon is underlain[3] by about 700 feet of white quartzitic sandstone, and this in turn by 30 to 50 feet of glauconitic sandstone with belemnites and *Olcostephanus*. In the Salt Range, Koken shows that there is, at Daoud Khel, 13 metres of glauconitic sandstone with *Olcostephanus* and *Belemnites subfusiformis*, evidently the same horizon as the Valanginian of the areas above mentioned; this is succeeded by ten metres of white sandstone with brown markings. This white sandstone may be provisionally correlated with the white quartzitic sandstone of the Samana range, and the age is therefore older than Gault but younger than basal Cretaceous. Above this at Daoud Khel, comes two metres of ferruginous marls, followed by limestone with Eocene fossils. The section at Daoud Khel therefore shows a stratigraphical gap between the white sandstone, presumably of Lower Albian or Aptian age, and the ferruginous marls, which comprise the basal bed of the Eocene suite, and which Koken regards as referable to the Danian or *Cardita beaumonti* horizon, but which is probably basal Laki.

Absence of Cenomanian in Salt Range.

Koken's work.

Middle and Upper Cretaceous stratigraphical gap.

The widespread stratigraphical gap in North-West India between the Gault and the Upper Cretaceous or between the Gault and the Eocene, pointed out already in my paper above quoted, is confirmed by recent work.

Mr. Lahiri was fortunate enough to find good sections through the Giumal-Spiti shale unit in the west of the Attock district. But as a rule, in the centre and east of the district, such sections are not to be found. The following is a typical example of a section through-

Section through Giumals and Spiti shales in Kawa Gar.

[1] H. G. Seeley, 'Fossils from Cretaceous Strata in the Salt Range', *Rep. Brit. Assoc.*, LXXII, p. 604, (1902) and *Geol. Mag.*, IX, p. 471, (1902).

[2] E. Koken, 'Kreide und Jura in der Salt Range', *Centralblatt f. Min. Geol. unl Pal.*, p. 439, (1903).

[3] L. M. Davies, 'Introductory Note to Fauna of Samana Range', *Pal. Ind.*, N. S., Vol. XV, Pt. I, p. 6, (1930).

the series; this section is from the Kawa Gar hill range south of Dhok Umre village:—

	Feet.
Kioto limestone	*thickness not measured.*
Ferruginous, banded sandstone	40
Variegated, coarse sandstone	60
Not seen	20
Sandy limestone with shells	9
Mainly sandy limestone with shells (*ill seen*)	80
Sandy limestone with a few shells	45
Shales	30
Shell limestone	24
Some concealed strata, and then Kioto limestone.	

Here the Giumals are caught into the Kioto limestone by isoclinal folding, and it is difficult to say what is the top and what the bottom of the section, or whether there is or is not reduplication. The shell limestone is not thicker than that of the southern Hazara section. I imagine that the oldest bed is the ferruginous sandstone, and that the section is reversed. Generally only the shell limestone remains and the softer beds are sheared away. I have already suggested that the shell limestone may be of Lochambel age.

CHAPTER III.

TERTIARY MARINE FORMATIONS.

Shales North of Kawa Gar.

In the Kawa Gar hills, on the northern side, between Jassian and Chak Akhori villages, there intervenes between the complex of Kioto and Giumal rocks, which constitute the main range, and the narrow range of Hill Limestone to the north, a valley in which shales appear at various points, but which are frequently obscured by recent deposits. These shales extend for upwards of five miles in the valley. They appear to underlie conformably the Hill Limestone, but there is a band of ferruginous pisolite or hematite-shale, six feet thick, between them and the Hill Limestone. This is exposed on a footpath leading through the hills and running south-west from Pind Trer. The shales are much twisted and crumpled near the junction with the Kioto limestone. I regard them as stratigraphically part of the Eocene suite.

The shales are unfossiliferous, and consequently their age is uncertain, but, if they are a downward extension of the Eocene suite of rocks, their age will clearly depend upon the age of the ferruginous pisolite and hematite-shale which caps them. This ferruginous pisolite will be dicussed in the following section, but it is sufficient here to state that I regard it as Lower Laki, and not Danian (*Cardita beaumonti*) age, as hitherto supposed.

The shales are of a light blue colour with buff jointings and partings, and break into small cubes and sharp-edged fragments. They contain bands of hard calcareous sandstone four to six inches thick and of a fine grain. The shales are much twisted and crumpled near their junction with the Kioto limestone, but are undisturbed where they abut on the Hill Limestone. On the footpath south-west of Pind Trer, they are capped by 12 feet of buff, nodular, sandy limestone, and then by six feet of hematite-shale. Here the shales just below the limestone are marly and nodular. A similar succession is seen east of Chak Akhori.

Near the villages of Bibraki and Pathargarh, which lie about two miles south by west of Hasan Abdal, shales underlie the Hill Limestone. These shales are dark blue or black, and at first sight not unlike the softer and more friable type of Attock slate, but they contain small nummulites, which fix the age as Eocene. But there is no trace of the ferruginous pisolite between these shales and the Hill Limestone.

In Hazara, C. S. Middlemiss[1] shows that the Hill Limestone (Nummulitic Limestone) is underlain by variegated sandstone with coal, and this in turn by ferruginous pisolite. Underneath this again is a grey limestone, the age of which is uncertain, and there is nothing, exactly corresponding to the Kawa Gar shales.

The Ferruginous Pisolite.

Thickness and relationships.

In many sections in the Kala Chitta and elsewhere, the junction of the Nummulitic or Hill Limestone with the beds below (Kiotos or Giumals) is sheared and no trace of the ferruginous pisolite remains. But in the less disturbed sections, this stratum is generally present. It is generally five or six feet thick, and is overlain by a bed known sometimes as the Variegated Sandstone,[2] but which is often shaly in white and pink bands, or again calcareous sandstone in white pink and purple. In the Hasan Abdal hill, the rock overlying the ferruginous pisolite is a soft, nodular, cream to yellow limestone, which doubtless is a calcareous facies or an upward extension of the variegated sandstone of other sections. This limestone is 60 feet thick. As a rule, the variegated sandstones in the Kala Chitta sections are only a few feet (five to ten) thick. Above these rocks comes the Hill Limestone.

Not of *Cardita beaumonti* age.

Sir Edwin Pascoe[3] states that in the Salt Range, a basal hematite band, often pisolitic is followed by variegated sandstones or dark foraminiferal limestone, above which come gypseous shales, with coal. He adds that *Cardita beaumonti* characterises these shales and that plant fragments are common. If this were the case, we should infer that the suite of shales, variegated sandstones and ferruginous

[1] *Op. cit.*, p. 40.
[2] C. S. Middlemiss, *op. cit.*, p. 40.
[3] *Mem. Geol. Surv. Ind.*, XL, Pt. 3, p. 343, (1920).

pisolite is of Danian age. But Sir Edwin Pascoe appears to have been misled by statements in previous literature.[1]

It is clear from Wynne's original account[2] of the shales supposed by Sir Edwin Pascoe to contain *Cardita beaumonti*, that they are Eocene and not Danian. Wynne states that nummulites are common throughout, and that *Orbitolites* and *Alveolina* occur in the lower beds. Wynne mentions that the base of this suite is marked by—

'a variegated white and red clayey hematitic band, which often assumes the character of pisolitic hematite or the brownish look and polished surface of earthy laterite.'

Variegated sandstones above Pisolite are Laki, not Danian.

A. Fleming[3] mentions certain fossils from the calcareous sandstone below the alum shales of the Salt Range. These fossils were described by D'Archiac and Haime,[4] and the identifications were revised by L. R. Cox.[5] They are as follows :—

Crommium ? dolium.
Pachycrommium flemingi.
'Cerithium' flemingi.
Keilostoma subturricula.
Terebellum cf. *distortum.*

[1] The first mention of *Cardita beaumonti* beds in the Salt Range appears to be that of W. T. Blanford in 1880 (*Mem. Geol. Surv. Ind.*, XVII, p. 36) where the opinion of Dr. Waagen is quoted that the Olive Group (now known to be Carboniferous) is the equivalent of the *Cardita beaumonti* beds of Sind. This is followed by W. Waagen in 1887, but Waagen does not say that he recognised the fossil, merely the beds, which is a vastly different matter, and merely opinion, not evidence. *See* W. Waagen, 'Die Carbone Eiszeit', trans. by R. B. Foote (*Rec. Geol. Surv. Ind.*, XXI, p. 115). This statement that the *Cardita beaumonti* beds occur in the Salt Range is repeated in 1889 by W. King (*Rec. Geol. Surv. Ind.*, XXII, pp. 156, 157) who quotes an extract from Waagen. The next mention of the Salt Range *Cardita beaumonti* beds is the second edition of the Manual of the Geology of India (1893), p. 353, written by R. D. Oldham. The statement has now become a text-book fact. There is a further mention of the horizon in F. Noetling's paper 'Beitrage zur Geologie der Salt Range', *Neues Jahrb. f. Min., etc.*, Beilage-band XIV, p. 414, (1901). Subsequently the existence of this horizon in the Salt Range has not been questioned, although the Olive series is no longer regarded as Cretaceous. Nevertheless, the whole tissue of theories built on the supposition of a *Cardita beaumonti* (Danian) base to the Salt Range Eocene must fall, as soon as it is realised that the fossil is unknown in the Salt Range. *See* also *Pal. Ind.*, Ser. X, Vol. IV, p. 59, (1887).

[2] *Mem. Geol. Surv. Ind.*, XIV, p. 106, (1878).

[3] A. Fleming, 'Report on the Geological Structure and Mineral Wealth of the Salt Range', *Journ. As. Soc. Beng.*, XXII, pp. 333 and 454, (1852).

[4] Vicomte d'Archiac and J. Haime, 'Description des Animaux Fossiles du Groupe Nummulitique de l'Inde', Paris, (1853).

[5] L. R. Cox, 'A Contribution to the Molluscan Fauna of the Laki and Basal Khirthar Groups', *Trans. Roy. Soc. Edinb.*, LVII, Pt. I, No. 2, p. 29, (1931).

Rimella jamesoni.
Volutospina sihesurensis.
Volutospina teelaensis.
Crassitellites salsensis.

L. R. Cox shows that this horizon is of Laki age, probably well down in the Laki.

It is clear both from Fleming's account and from that of A. B. Wynne,[1] that the calcareous sandstone underlying the alum shale is the variegated sandstones underlying the gypseous shales with coal exposed north of Khewra. The alum shales are identical with the shales with coal. It is now clear that the true age of these sandstones is Laki and not *Cardita beaumonti* or Danian, as has been erroneously supposed.

Beds at Hasan Abdal above Pisolite are of Laki age.

In the Hasan Abdal hill, it has been noted that there are 60 feet of nodular, cream to yellow limestone. These limestones have yielded a species of *Echinolampas* (probably a new species) allied to, but not identical with the Laki species, *E. lepadiformis*, Duncan and Sladen. Again, on the Bajar hill, four miles east of Hasan Abdal, there is the same succession from the Ferruginous Pisolite upwards. Here, the yellow nodular limestones contain a badly preserved *Nautilus*, a few nummulites, and broken oyster shells. Here again, the probability is that we are dealing with the Laki, and there is no doubt that the nodular limestones immediately above the Ferruginous Pisolite are Laki and not Danian.

Correlation with Sind section.

The view that the Ferruginous Pisolite is basal Laki and not Danian has been advocated by D. N. Wadia and L. M. Davis,[2] who compare it with the unconformity between the basal Laki and the Ranikot in the Kohat district. In Sind, the base of the Laki is marked by a bed of laterite 25 feet thick.[3] Although it is a far cry from Sind to the Salt Range and Kohat, yet it may be noted that the laterite or ferruginous pisolite, or hematite-shale at the base of the Laki, is a very widespread feature, and the correlation is reasonable, considering the fossil evidence.

[1] *Mem. Geol. Surv. Ind.*, XIV, p. 301, (1878).
[2] *Trans. Min. Geol. Inst. Ind.*, XXIV, p. 210, (1929).
[3] W. F. L. Nuttall, *Quart. Journ. Geol. Soc.*, LXXXI, pp. 417-453, (1925).

Extent of Ranikot deposits in North-West India.

We may therefore dismiss the old idea of the existence of the *Cardita beaumonti* horizon in the Salt Range, and replace it by the conception of a wide-spread unconformity at the base of the Laki, which is usually marked by red beds. The Laki rests sometimes upon Giumals, sometimes upon Kioto limestone, sometimes (in the Salt Range) upon Carboniferous, Permian, or Trias. No trace of Ranikot fossils is known in North-West India below the Laki, except in the Kohat district near Thal and the Samana range, with the addition of the very curious occurrence of Ranikot nummulites in the Salt Marl of the Salt Range near Khewra, which were discovered by E. R. Gee.[1] It may be noted that D. N. Wadia and L. M. Davies,[2] and again L. M. Davies[3] have suggested an Upper Ranikot or basal Laki age for the Salt Marl of Kohat. I do not propose to discuss the vexed question of the age of the Salt Marl here, but wish to note that although there are still many difficulties to be explained, I now accept a Ranikot age for it.

The Hill Limestone.

Extent.

The Hill Limestone is the dominant formation of the Kala Chitta, and of the Khair-i-Murat, and is found in the Kawa Gar and Kheramar hills. It forms the higher scarps of the Salt Range, and it extends to Hazara and Kohat. In Hazara, Middlemiss[4] gives a thickness of 200 feet of massive limestone, with 300 feet of shales, marls, and concretionary limestone above. In Attock district, Sir E. H. Pascoe[5] states that the maximum thickness of the Hill Limestone is 1,650 feet in the Kala Chitta, and only 500 to 600 feet in the Salt Range. R. van. V. Anderson[6] states that in the Salt Range in the western portion not far from the Indus, the thickness is 700 feet at a maximum, but that the thickness progressively declines as one travels along the Salt Range eastwards. He regards the thickness along the foothills of the Himalaya as up to 1,800 feet.

[1] Director's General Report, Geological Survey of India, *Rec. Geol. Surv. Ind.*, LVI, p. 32, (1932).
[2] *Loc. cit.*
[3] *Pal. Ind.*, N. S., Vol. XV, Pt. I, p. 14, (1930).
[4] *Op. cit.*, p. 38.
[5] *Op. cit.*, p. 344.
[6] *Bull. Geol. Soc. Amer.*, Vol. 38, p. 670, (1928).

In the Hill Limestone of the Kala Chitta, *Assilina granulosa*, the zone foraminifer of the Laki, is of common occurrence. In microscope sections, I have seen traces of what are probably *Alveolina* and of *Textularia*. Mr. Lahiri also mentions *Assilina granulosa* together with *Lucina* sp., *Conoclypeus* sp. and *Isis* sp. He also mentions a nummulite which he doubtfully refers to *Assilina ranikoti*, Nuttall. This species characterises the Upper Ranikot, and is not known from the Laki, nor has it hitherto been found in company with the Laki *Assilina granulosa*.

Fossils and age.

D. N. Wadia and L. M. Davies[1] find the representative of the Hill Limestone in Kohat to contain *Nummulites atacicus*, *Assilina granulosa*, *Alveolina oblonga*, *Orbitolites complanatus* and *Hemiaster apicalis*. These are all Laki species, but *N. atacicus* and *O. complanatus* extend upwards to the Khirthar.

Hill Limestone of Kohat.

In the Salt Range, north of Naushahra, Mr. Lahiri found *Nummulites atacicus*, *Assilina granulosa*, *Alveolina* sp. and *Conoclypeus* sp. in the Hill Limestone.

In Hazara, Middlemiss mentions *Nummulites* and *Montlivaultia* from this horizon. Sir Edwin Pascoe notes that the lower part of the Hill Limestone stage is a blue or cream-blue limestone mottled with buff and ochre; this is followed by concretionary limestones with *Assilina granulosa*. This consists of irregular lumpy layers with thin shale partings, which are sometimes carbonaceous. These are followed by massive limestones separated by bands of concretionary limestone.[2]

Near Surg village, about eight miles south-west of Campbellpur, there is a bed of gypsiferous shale with thin seams of carbonaceous shale and coal. This bed is 100 feet thick, and the coaly bed in it (consisting of carbonaceous shale with lenticles of coal) is $2\frac{1}{4}$ feet thick. The bed of gypsiferous shale is interbedded with the nummulitic limestone. It evidently corresponds to the shale zone with *Assilina granulosa* noticed by Sir Edwin Pascoe. It may also be compared with the alum shale and the shale with coal of the Salt Range.

Coal seams in Hill Limestone.

[1] *Trans. Min. Geol. Inst. Ind.*, XXIV, p. 208, (1929).
[2] *Op. cit.*, p. 385.

In Hazara, Middlemiss associates the coal with the variegated sandstone overlying the Pisolite. I have noted above that the variegated sandstone sometimes becomes calcareous and in the Hasan Abdal hill appears to be represented by actual limestones. It is probable that the horizon is the same both in the Kala Chitta, in Hazara, and in the Salt Range, but that the sandstone facies is represented at least in its upper part by a calcareous facies in the Kala Chitta.

Variegated sandstone and coal at base of Hill Limestone.

Mr. Lahiri notes that the Hill Limestones give out a fetid odour when broken. The colour is grey to bluish-grey, but a lighter coloured bed, often blotched with ochre tints, and resembling Kioto limestone, is sometimes found intercalated. Another type of bed, is a thin-bedded, ochre-stained limestone with fragments of lamellibranchs; this recalls the Giumal limestone to some extent. Mr. Lahiri adds that calcareous shales and shaly limestone are frequently interbedded with the massive Hill Limestone. Sometimes the shales are carbonaceous and coaly. He also notices that a thin greenish sandstone is sometimes found interbedded with the concretionary limestones.

The Chharat Series.

The name Chharat series is due to E. S. Pinfold,[1] who divides the rocks resting upon the Hill Limestones into three subdivisions, as follows :—

Subdivisions.

(3) Nummulite Shale, from 50 to 200 feet thick.

(2) Thin bedded limestones and green shales, thickness about 100 to 200 feet.

(1) Variegated Shales with bleached limestone bands, thickness 300 to 500 feet.

The type section from which the above description and measurements are taken is the stream east of Chharat, a village about five miles west by north of Fatehjang. The thickness of the Chharats as a whole, is thus seen to vary from 450 feet to 900 feet. The lowest beds, the Variegated Shales, conformably overlie the Hill Limestone, and are separated at Chharat from the latter by passage beds of white chalky limestones with fibrous gypsum, sometimes with ochre, and carrying sulphur in the more shaly bands. Pinfold

[1] *Rec. Geol. Surv. Ind.*, XLIV, pp. 137 *seq.*, (1918).

states that this horizon is the source of the oil seepages of Chharat, Golra, and Rutta Hotar. The Variegated Shales, which succeed these passage beds are brightly coloured with thin bleached limestone bands; fragments of bones of crocodilians and chelonian plates occur, and shells of *Planorbis* are common.

The middle group of limestones and shales contain nummulites in their upper part, and abundant casts of lamellibranchs and gastropods.

The highest group, the Nummulite Shale, is an easily recognised horizon; it consists of green shale, almost entirely made up of compacted nummulite tests.

The Chharat series extends along the southern, and in the eastern part of Attock, sometimes on the northern flanks of the Kala Chitta.

Extent.

It continues across the Indus to the Kohat district where, in the section described by D. N. Wadia and L. M. Davies,[1] its thickness is between 750 and 900 feet. In Hazara, the Chharats, or at any rate their lower subdivision, is, according to Pinfold,[2] represented by the Kuldana beds of Middlemiss.[3] G. E. Pilgrim[4] applied the name Kuldana to the basal Murree beds near Chharat, which overlie the Chharats,

Thickness.

and which are of much later age (Lower Burdigalian or Upper Aquitanian); this has proved unfortunate. The correlation of the Kuldanas of Hazara with the basal Murrees appears to me to be wrong, and I agree with Pinfold's view that they represent the Chharats.

In the Khair-i-Murat hills south of the Kala Chitta, the two upper subdivisions of the Chharats are absent; there are according to Mr. Lahiri, about 200 feet of chalky limestone (passage beds) overlying the massive Hill Limestone, and then 200 feet of green shale and marly limestone. This last group corresponds to the Variegated Shale of the Kala Chitta. *Planorbis* occurs at this horizon at Galli Jagir. Thus the thickness of the Chharats is here only 200 feet.

In the Salt Range, the Chharats proper are absent, but there are in places passage beds, shaly limestones, marls and shales, sometimes 20 feet thick or so, overlying the massive Hill Limestone.

[1] *Trans. Min. Geol. Inst., Ind.*, XXIV, p. 208, (1929).
[2] E. S. Pinfold, *op. cit.*, p. 148.
[3] C. S. Middlemiss, *op. cit.*, p. 42.
[4] G. E. Pilgrim, *Rec. Geol. Surv. Ind.*, XL, p. 187, (1910).

In other sections, the basal Murrees (Kamlials of Pascoe) rest directly upon the Hill Limestone. At Kallar Kahar, the Murrees rest directly on the Hill Limestone, but at Dhok Talian, there are about 20 feet of passage beds intervening.

Age and comparison with Kohat area.

The nummulites of the Nummulite Shale consist almost entirely of the species *Assilina exponens* and *Nummulites atacicus* (*biarritzensis*). Mr. Lahiri has also collected *Discocylina javana*, and both of us have identified an *Assilina* which appears identical with *Assilina papillata*, Nuttall. The latter however occurs, according to Nuttall,[1] in the upper division of the Middle Khirthar, and not in the lower. However, it is possible that we must extend the range downwards to the lower part of the Middle Khirthar as well. It seems best to regard the Nummulite Shale as belonging to the lower part of the Middle Khirthar. L. M. Davies [2] records also the occurrence of *N. obtusus* (*N. perforatus* auctores) from the Nummulite Shale, and L. R. Cox notes the occurrence of *Ostraea* (*Pycnodonta*) *brogniarti* and *Chlamys wynnei* from the Nummulite Shale of Kohat.

The middle division of the Chharat series, that is, the 'Limestones and Shales' group, has yielded in Attock district many casts of mollusca; the only one that could be specifically identified was *Cardita subcomplanata*, D'Arch.; other species were *Cardium* sp., *Meretrix* sp., *Tellina* sp., *Lucina* sp., *Miocardia* sp. and *Corbula* sp.

Kohat shale.

L. M. Davies has worked out the palæontology of this horizon in Kohat. He terms it the Kohat shale. The foraminifera [3] are *Nummulites laevigatus*, *N. atacicus*, *Dictyoconoides kohaticus*, *Alveolina oblonga*, *A. javana*, and *Nummulites* cf. *raymondi* at base. The mollusca have been identified by L. R. Cox,[4] who quotes in a footnote the latest views of L. M. Davies that the Kohat shale is Lower Khirthar in age. Cox's list of mollusca from this bed is:—

Velates perversus.
Cepatia cepacea.
Hippochrenes cf. *amplus.*
Digitolabrum ? zigni.
Oliva virginiae.

[1] *Rec. Geol. Surv. Ind.*, LIX, p. 121, (1926).
[2] *Trans. Min. Geol. Inst. Ind.*, XX, p. 207, (1926).
[3] *Op. cit.*, XXIV, p. 208, (1929).
[4] *Op. cit.*, pp. 26, 28.

Involuta daviesi.
Euphenax jamaicensis.
Ostraea (*Liostraea*) cf. *roualti.*
Chlamys wynnei.
Spondylus perhorridus.
Lucina (*Loripinus*) *pharaonis.*
Lucina (*Loripinus*) *kohaticus.*
Meretrix cf. *sulcataria.*
Blagraveia sindensis.
Blagraveia corrugata.
Cardium halaense.
Cardium salteri.
Corbula (*Bicorbula*) *subexarata.*
Panopaea cf. *intermedia.*
Fistulana elongata.

This fauna in L. R. Cox's opinion marks the base of the Khirthar.

The lowest division of the Chharats, the Variegated Shales, contain *Planorbis* and vertebrate remains. They are freshwater in facies and there are no zone fossils by which their age is determinable, but the probability is that they are uppermost Laki.

Kuldanas of Hazara.

In the area north of the Kala Chitta south of the village of Shahpur, which is about $4\frac{1}{2}$ miles north of Fatehjang, thin reddish sandstone beds are intercalated with the Variegated Shales. The development of sandy beds by a change of facies at this horizon makes the series closely resemble the Kuldanas of Hazara, and adds strength to the opinion that the Kuldanas are to be correlated with the Chharats.

Nummulitics near Dandi Jaswal.

Mention should also be made of a small outcrop of Nummulitics near Dandi Jaswal [1] on the Indus the topmost bed of which consists, according to Mr. Lahiri, of a thick, massive limestone containing abundant *Alveolinae.* From a preliminary examination of the fossils obtained from this bed and its underlying shales, Mr. Lahiri thinks that they probably correspond in age to the 'Limestones and Shales' horizon of the Chharat series. This confirms the views of E. S. Pinfold [2] who also regarded the topmost limestone of this area and of the Panoba area to the west as equivalent to this horizon.

[1] *Rec. Geol. Surv. Ind.*, LXIII, pp. 138-139, (1930).
[2] *Op. cit.*, XLIX, p. 147, (1919).

CHAPTER IV.

TERTIARY FRESHWATER FORMATIONS OF THE POTWAR.

Introduction.

Definition of terms Murree and Siwalik.

The Tertiary freshwater deposits of the Potwar have been divided by A. B. Wynne [1] into two series, the Murrees below, and the Siwaliks above. Of these two terms, the first is a local term, and the type area is Murree cantonment in the neighbouring district of Rawalpindi. The term Siwalik on the other hand is due to H. B. Medlicott [2] and is taken from the country between the Ravi and the Ganges rivers, where the Himalayan foothills are composed of these rocks. The term Siwalik is therefore a transported term, and its use by A. B. Wynne for the Potwar rocks implies a correlation with the rocks of the Himalayan foothills, which, in view of the fact that the geology of the intervening country was then and still is imperfectly known, was perhaps somewhat daring. The term Siwalik has been transported still further from its original home and applied to the Manchars of Sind by W. T. Blanford, [3] and by G. E. Pilgrim, [4] and it has been argued that the base of the Siwaliks is or should be the same in all three sections, *viz.*, that of the Siwalik hills, of the Potwar, and of Sind. It will, however, be at once seen that the Sind section differs greatly from the other two in that marine conditions persisted in Sind at an age when freshwater deposits were being laid down in Baluchistan and the Punjab. For the marine Gaj of Sind is homotaxial with the Bugti beds of Baluchistan, and the Lower Murrees of the Punjab. The question then arises, should we draw a dividing line between the Murree

[1] *Rec. Geol. Surv. Ind.*, X, p. 107, (1877).

[2] *Mem. Geol. Surv. Ind.*, III, Pt. 2, p. 13, (1864).

[3] *Mem. Geol. Surv. Ind.*, XVII, p. 57, (1879); *ibid.*, XX, p. 160, (1883).

[4] *Rec. Geol. Surv. Ind.*, XXXVII, p. 163, (1908); XL, p. 189, (1910); XLIII, p. 314, (1913).

series and the Siwalik series in the Punjab, so as to include the Punjab equivalents of the fauna of the basal Manchars in the Siwaliks, or should we choose as far as possible a natural, easily mapped, lithological boundary, by which the two series may be easily separated in the field. In considering this question, the Siwalik hills sections are of no use to us, since the Lower Siwaliks (Nahan beds) are unfossiliferous, and the correlation is uncertain. In my view, geological maps should always be based as far as possible upon easily recognisable field boundaries.

In the map accompanying A. B. Wynne's paper, above quoted, the dividing line between the Murrees and the Siwaliks was drawn at the base of the Chinji beds, and above the Kamlial beds. The rocks mapped as Kamlial, south of Chinji by Sir Edwin Pascoe, [1] were shown as Murree by A. B. Wynne. The Kamlials of the type locality, the Khaur oilfield, are included by A. B. Wynne in the Murrees. In other parts of Wynne's map, despite the discrepancies brought out by the new map, it is abundantly clear that he regarded the base of the Chinjis as the base of the Siwaliks.

Dividing line between Murrees and Siwaliks according to Wynne.

The point is also clear from Wynne's text, on page 113, the hardness of the Murree sandstones is a feature to be distinguished from the softness of the Siwalik sandstones. The Murrees contain sparse vertebrate remains; the Siwaliks have an abundance of vertebrates. On page 119, he speaks of the predominance of red over purple in the clays, the cleaner colour of the now softer sandstones, and the brighter colours of the clays and sandstones, which indicate the passage from Murree to Siwalik rocks. This description applies to the passage from the Kamlials to the Chinjis, and could not possibly apply to that from the Upper Murrees to the Kamlials, for the latter passage is one from softer sandstones and brighter and redder clays below to harder sandstones and darker coloured clays above.

Base of Chinjis mapped by Wynne and base of Siwaliks.

The boundary between the Chinjis and the Kamlials is usually sharp. The soft grey sandstones, bright red clays and concretionary conglomerates of the Chinjis pass downwards into the harder olive sandstones and subordinate clays of a darker red or sometimes

[1] *Mem. Geol. Surv. Ind.*, XL, Pl. 88, (1920).

greenish, colour, and the harder pseudo-conglomerates of the Kamlials. The Kamlial sandstones usually form long ridges rising, in the country west of Kallar Kahar and north of the Salt Range, to 500 feet or more above the level of the Chinji outcrops to the north. The Chinjis, on the other hand, never form prominent hill-ranges, but usually constitute areas of low relief, excavated by streams below the level of the surrounding country. They are a soft belt of beds lying between the hard Kamlial sandstones below, and the massive and fairly hard sandstones of the Nagri stage of the Middle Siwaliks above. Thus their softness has caused valleys to form along their outcrops, and the line of Kamlial sandstone hills on one hand, and of Nagri sandstone hills on the other, enclosing them, is an easily recognised feature in the landscape. While the Kamlials and the Nagris are predominantly arenaceous, the Chinjis have a high percentage of soft clays. R. van V. Anderson[1] states that sandstone constitutes four-fifths of the Kamlials, while the Chinjis have about 70 per cent. of what he prefers to call 'siltstone' rather than clay.

Indefiniteness of boundary of Kamlials and rest of Murrees.

While the transition from Kamlials to Chinjis is fairly sharp, such is not the case with the transition from Upper Murrees to Kamlials. No two geologists appear to be in complete agreement as to where to draw this boundary. A comparison of E. H. Pinfold's first map[2] with that subsequently published in Sir Edwin Pascoe's memoir[3] (map also due to E. S. Pinfold), will show that the 'Crest Sandstone' is included in the Kamlial stage in the first, and in the Murree series in the second map. In the Khaur oilfield, it is a simple matter to walk along the strike of a given bed, and produce a geological map. But in order that the boundary may be of more extended use, it must have some distinguishing feature which makes it definitely recognisable. Neither Mr. Wadia, who mapped the adjoining country, nor Mr. Lahiri, nor myself have been able to agree as to the lower boundary of the Kamlials. The transition is so gradual that there is often no other course but to fix upon a given bed, and map along its strike.

Disagreement of geologists.

[1] *Bull. Geol. Soc. Amer.*, Vol. 38, p. 684, (1928).
[2] *Rec. Geol. Surv. Ind.*, XLIX, Pl. 4, (1918).
[3] *Mem. Geol. Surv. Ind.*, XL, Pl. 78 A, (1920).

R. van V. Anderson notes that the post-Eocene succession, although showing variations in colour, mineral grain, and the grouping of beds at different horizons, is essentially one system of deposits of a fairly homogeneous type. He proposes to call the fresh-water deposits of the Potwar the *Nimadric system*,[1] thus doing away with the division into Murrees and Siwaliks.

Views of R. van V. Anderson.

While this suggestion has the advantage of avoiding the present unworkable division at the base of the Kamlials, there is the alternative plan, which is here recommended, of going back to Wynne's original boundary line at the top of the Kamlials, and including the Kamlials in the Murree series.

Of the Siwalik-Murree boundary at the base of the Kamlials adopted by Pinfold and Pascoe, R. van V. Anderson writes :—

'No recognisable dividing line nor definite basis of division between the Murree and the Siwalik have been established, and it is not unlikely that in places the lower portion of the terrain that lends itself to mapping as Kamlial actually represents what is elsewhere called Murree, especially where the terrain is thick. Its thickness is 900 feet, as set off in the Khaur anticline, from the underlying variegated silt-stone beds, which Pinfold considered to be representative of the Upper Murree. There is no sign of a stratigraphical break, and the separation is made on the basis of lithology, the beds termed Kamlial being a ridge forming body mainly of sand-stone.'

'In the northern belt of outcrop of this stage about 10 miles north of Khaur (Chirpar Hills) and extending westward toward the Indus (near Gulial, etc.) and northeastward to south of Rawalpindi and beyond, a total distance of over 85 miles, the thickness of beds that might be correlated with the Kamlial on lithologic grounds ranges between 1,000 and 2,000 feet. This may include beds at the base equivalent to those called Murree at Khaur, but part at least of the increase is believed to represent northward thickening of the stage. The other main belt of outcrop forms the southern border of the Siwalik area, running in a general east-west direction for over 120 miles along the Salt Range and its appendages. There, the formation has a thickness ranging from about 900 feet upwards. Much of the thickening takes place at the base of the terrain and probably represents beds called Murree in the north. The varying thicknesses of this Kamlial-Murree terrain in the southern belt are approximately as follows : 1,400 feet near the Indus, 100 feet over the sharp bend and highest portion of the Salt Range, 30 miles south-east of the Indus, gradually increasing thence eastward to 1,300 feet in the Central portion of the range, to 1,550 feet near Kallar Kahar, and to 2,070 feet on Diljabba Ridge, 25 miles north-east from Kallar Kahar.'

The above accurate survey of the Kamlial outcrops in and on the margins of the Potwar shows the difficulty of separating the Kamlials from the Murrees.

[1] *Op. cit.*, p. 673.

Term Kamlial due to E. S. Pinfold.

The term Kamlial is due to E. S. Pinfold,[1] but it was first mentioned by G. E. Pilgrim [2] having been adopted by him from Pinfold.

Inclusion of Kamlials in Siwaliks by G. E. Pilgrim and G. S. Pinfold.

Pilgrim showed that the vertebrate fauna of the Kamlials is the same as that of the basal Manchars in Sind. It was, therefore, considered necessary to place the Kamlials in the Siwaliks, because (*a*) the Manchars had been equated with the Siwaliks, and (*b*) the Potwar Siwaliks had been equated with those of the Siwalik hills.

Pilgrim,[3] in a former paper, is inclined to correlate the Nahans of the Siwalik hills with the 'Lower Siwaliks of Chinji' and there has been, so far as I know, no reason to modify this conclusion. There are very few fossil vertebrates from the Lower Siwaliks of the Siwalik hills, and we cannot say whether the lower Manchar zone exists as a fossiliferous horizon there and whether it lies below or above the local Kasauli (Upper Murree)-Siwalik boundary. We are not yet in a position to equate the so-called Siwaliks of the Potwar with those of the type-area (Siwalik hills), but we think that they roughly correspond. This is due to the close resemblance between the Murrees and the Kasauli-Dagshai beds, and the suspicion that they are homotaxial.

There appears to be no reason why a section so far distant as Sind, and differing so profoundly from those of the Potwar and the Siwalik hills, in respect of the much later persistence in Sind of marine conditions, should so influence our field mapping in the Potwar as to force us to abandon a natural dividing line dividing the freshwater tertiaries into two groups,—I mean that line between the Kamlials and the Chinjis—for the indefinite, vague and gradual passage between the Upper Murrees and Kamlials.

Pinfold distinguishes the Kamlials from the Murrees by the presence in the former of abundant vertebrate remains. This distinction is less pronounced in Western Attock, where the Kamlials are not too abundantly fossiliferous, and where Mr. Lahiri has found several fossiliferous horizons in the Upper Murrees.

[1] *Rec. Geol. Surv. Ind.*, XLIX, p. 154, (1918).
[2] *Rec. Geol. Surv. Ind.*, XLVIII, p. 99, (1917).
[3] *Rec. Geol. Surv. Ind.*, XL, p. 193, (1910).

Classification adopted in present memoir.

I propose then to adopt in this memoir, as the dividing line between the Murrees and the Siwaliks, the base of the Chinjis. The scheme of subdivision will then be :—

Siwalik series	Upper Siwaliks, (Tatrot stage). Middle Siwaliks, Dhok Pathan stage. Nagri stage. Lower Siwaliks, Upper Chinji stage. Lower Chinji stage.
Murree series	Kamlial stage. Infra-Kamlial (formerly called 'Upper Murree') stage. Lower Murree stage, with Fatehjang zone at base.

This grouping applies to the freshwater deposits of the Attock district. It will be noticed that there are no beds belonging to the Pinjor or Boulder Conglomerate stage of the Upper Siwaliks, and that the Bhandar beds above the Dhok Pathan stage have not been recognised. It has been possible in most areas to separate the Nagris from the Dhok Pathans, but the Upper have not been separated from the Lower Chinjis. The separation of the Kamlials from the Infra-Kamlial (Upper Murree) stage has been effected in all areas except the Kamlial-Murree outcrop immediately north of the Salt Range, where it is not possible to make such a separation. I shall now proceed with the description of formations.

The Fatehjang Zone or Basal Murrees.

Not Kuldanas.

The name Fatehjang zone is due to E. S. Pinfold,[1] who shows that the use of the term *Kuldana* [2] for this zone, which G. E. Pilgrim had adopted, was probably wrong, the Kuldanas of the type area [3] being probably Chharats, and much older than the Fatehjang zone.

Fossils and age.

G. E. Pilgrim [4] identified from the basal Murrees at Fatehjang the following species :—

Anthracotherium bugtiense.
Brachyodus cf. *africanus.*

[1] *Op. cit.*, p. 146.
[2] *Rec. Geol. Surv. Ind.*, XL, p. 187, (1910); XLIII, p. 265 and Pl. 27, (1913).
[3] *Rec. Geol. Surv. Ind.*, VII, p. 68, (1874).
[4] *Pal. Ind.*, N. S., Vol. IV, Mem. No. 2, p. 2, (1912).

Palaeochoerus pascoei.
Teleoceras fatehjangense.
Hemimeryx sp.

In a later paper[1] he observes that the presence of *Teleoceras fatehjangense* and *Hemimeryx* sp. would point to a slightly newer age for the Fatehjang zone than that of the Bugti beds. The age, he thinks, is Burdigalian.

It is commonly said that the Fatehjang zone is 'Gaj' in age, thus implying a correlation with the Gaj of Sind. However, the Lower Gaj is probably Aquitanian, and it is with the Upper Gaj only that a correlation can be made. This correlation is fairly certain, since the Upper Gaj probably extends throughout the Burdigalian, while the Fatehjang zone may be uppermost Aquitarian or lowermost Burdigalian. It is therefore certain that the fauna is very close in age to the marine fauna of the Upper Gaj. Mr. Lahiri has collected, from the Fatehjang zone, the following fossils :—

Teleoceras blanfordi.
Amphicyon shahbazi.
Brachyodus giganteus.

All the above occur also in the Bugti hills.

E. S. Pinfold describes the basal Murrees as brown ochreous sandstones with subordinate shales and much pseudo-conglomerate. Mr. Lahiri says that these rocks are, in the western part of the Kala Chitta, hard micaceous sandstones alternating with purple, sometimes earthy shale and frequent pseudo-conglomerate, the latter containing rolled assilines and nummulites derived from the Nummulite Shale below. He regards the thickness of the zone as 200 feet, but this is a purely arbitrary figure, as they grade insensibly into the rest of the Lower Murrees of which they are the basal zone.

Relationships to underlying rocks.

These beds rest with unconformity, marked by a basal conglomerate one foot or more in thickness, but without any discordance, upon the Chharats, and perhaps sometimes upon the Hill Limestones direct. Certainly the basal Murrees in the eastern Salt Range (which were mapped by Pilgrim as 'Kuldanas', that is, Fatehjang

[1] *Rec. Geol. Surv. Ind.*, XLIII, p. 264, (1913).

zone) rest directly on the Hill Limestone.[1] But although Pilgrim, on lithological grounds, regarded these beds as Fatehjang zone, he had no fossil evidence, and the continuation of these beds to the westward has been mapped in the neighbourhood of Chinji as of Lower Manchar or Kamlial age by Sir Edwin Pascoe.[2]

It may be that the Fatehjang zone mapped by Pilgrim in the eastern Salt Range is overlapped by the Kamlials as one travels westward. This is merely a plausible conjecture derived from the lithology of the beds, and cannot be proved or disproved without fossil evidence.

The Lower Murrees.

Thickness.

The Murree series is, according to A. B. Wynne,[3] 7,500 feet thick on the average, or, in another estimate, from 5,000 to 8,000 feet thick. Pilgrim gives a maximum thickness of 8,000 feet,[4] and R. van V. Anderson [5] says :—

'The total thickness of the Murree series is difficult to make out, owing to the close folding and severe faulting that it has undergone in the piedmont belt where it is best exposed. Subsequent work affords no basis for altering Wynne's early estimate of 5,000 to 8,000 feet.'

Wynne's estimate includes the Kamlials, but that of Pilgrim excludes them, and is probably too high. The Murrees attenuate on the north flank of the Salt Range, and over the central part of the Salt Range, Sir Edwin Pascoe and others think that only the Kamlial stage is present, but there is no doubt that in the eastern Salt Range, there are lower horizons than the Kamlials. The Murrees attain their maximum thickness south of the Kala Chitta. To the north of the Kala Chitta, except near Shah Ala Ditta in the Rawalpindi district,[6] the Murrees are absent and only Eocene or older rocks are seen.

Eastward, they form a V-shaped outcrop in the great Himalayan syntaxis described by D. N. Wadia,[7] and from there they run south-eastwards along the margin of the Himalaya, through the imper-

[1] *See* map, Pl. 27, *Rec. Geol. Surv. Ind.*, XLIII, (1913).
[2] *Mem. Geol. Surv. Ind.*, XL, Pt. 3, Pl. 88, (1920).
[3] *See Rec. Geol. Surv. Ind.*, X, pp. 113 and 119, (1877).
[4] *Rec. Geol. Surv. Ind.*, XLIII, Pl. 26, (1913).
[5] *Op. cit.*, p. 683.
[6] *See* map, Pl. 11, *Mem. Geol. Surv. Ind.*, LI, Pt. 2, (1928).
[7] *Rec. Geol. Surv. Ind.*, LXV, p. 189, (1931).

fectly known areas of Jummu and Gurdaspur into the country mapped by H. B. Medlicott[1] between the Ravi and Ganges, where they are called the Kasauli and Dagshai series.

The lower Murrees are several thousands of feet thick, perhaps about 4,000 feet, but an exact estimate is impossible. The Upper (Infra-Kamlial) Murrees are not much over 1,000 feet thick, but the actual thicknesses cannot be ascertained, both owing to the faulted and isoclinal structure, and to the fact that the passage from the Lower Murrees to the stage above is exceedingly gradual.

A. B. Wynne thus describes the difference between the Lower and the Upper (Infra-Kamlial) Murrees :—

Lithology.

'A strong purple colour pervades the whole lower portion of the group, which shows an endless alternation of red and purple clays, with purple and greyer, thick or thin sandstones and concretionary earthy or slightly calcareous bands. In the upper portions' (*i.e.*, the Upper Murrees, Infra-Kamlial stage) 'and among southern representatives of these Murree beds,' (*i.e.*, the 'Kamlials' of the central Salt Range) 'pale, soft, grey, or greenish sandstone zones are intercalated with the more usual purplish clays and sandstones.'[2]

R. van V. Anderson says :—

'In the upper part of the sequence called Murree, in apparently gradual relationship with the beds below' (*i.e.*, the lower Murrees) 'and above' (*i.e.*, the Kamlial beds) 'comes a softer and more predominently silty stage, at least some hundreds of feet thick, composed of gray reddish and purplish siltstone interbedded with gray and greenish gray sandstone.'[3]

The above descriptions of the Murree series do not require much amplification. In the Lower Murrees, purple and dark green, fine-grained sandstones alternate with dark, red and purple clays and shales. Pseudo-conglomerates are common but true conglomerates are rare. Nummulites (derived as pebbles from the beds below) are common in the basal beds, but are not confined to them; for similar nummulite-bearing beds occur as high as the Middle Siwaliks. The Lower Murree sandstone is hard and micaceous, but less coarse-grained than that of the Nagris or the Kamlials.

Fossils.

Veins of calcite are common, and occasional pieces of fossil wood occur. Vertebrate fossils are rare, but Mr. Lahiri collected from these beds near Kali Dilli a well preserved tooth of an anthracothere apparently *Hyoboops.*

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 2, (1864).
[2] *Op.cit.*, p. 118.
[3] *Op. cit.*, p 683.

The terrain of the Lower Murrees is striking in appearance by reason of the long steep ridges of hard sandstone running wall-like along the strike of the country. This is due to differential weathering in the alternate and usually vertical or steeply dipping beds of sandstone and shale. In the Murrees associated with the Khair-i-Murat hills, vertebrate remains, too fragmentary for identification, have been found; amongst these are bones and teeth of crocodile. Mr. Lahiri notes that the hard sandstone of the lower Murrees is used for building stone.

The Infra-Kamlial Stage or the 'Upper Murrees'.

The typical rocks of this stage are grey or 'pepper and salt' sandstones interbedded with purple and red shales and bands or pseudo-conglomerate. The sandstones are soft, and of a coarser grain than those of the Lower Murrees. There are, however, hard sandstones which form ridges along the strike.

Lithology.

While the Lower Murrees are mainly an arenaceous formation, in which the clay beds are subordinate, the 'Upper Murrees' contain more clays than sandstone. The tints of the clays are more of a red or cherry red colour, and less purple than those of the Lower Murrees. The beds might be mistaken for the Chinji stage of the Siwaliks at first glance, but the latter is still more argillaceous. Mr. Lahiri found in these beds, at a spot one mile east of Khidwal, a Rhinocerotid tooth, which he provisionally compares with *Aceratherium gajense* but there are points of difference which indicate that the species, though close, is not the same. Fragmentary fossils occur in other localities, amongst which are remains of *Mastodon* (*sensu lato*).

Thickness.

The thickness of this stage is uncertain, by reason of the indefinite character of its upper and lower boundaries, the transition both to Kamlials above and to Lower Murrees below being gradual. It is believed to be roughly 1,000 feet thick.

The Kamlial Stage.

The type area of this stage is, as has been mentioned above, the Khaur anticline. I have already alluded to the fact that in E. S. Pinfold's map, published in Sir Edwin Pascoe's memoir, the 'Crest Sandstone' is marked as Murree. Mr. Lahiri and I both

think that this sandstone should be included in the Kamlial stage. It contains abundant remains of vertebrates, and the incoming of numerous vertebrate remains is very suggestive of this horizon.

Thickness.

The thickness at Khaur, as has been stated, is 900 feet. In an extract from R. van V. Anderson's paper given above (p. 50), the thicknesses of the Kamlial stage in different localities is given. It is unnecessary to amplify this account which is accurate.

Distinction from Infra-Kamlials.

The Kamlials are distinguished from the stage immediately below ('Upper Murrees') by the more arenaceous character of the beds, the harder and darker-coloured sandstones and the darker red of the shales, the frequency of pseudo-conglomerate bands, and the abundance compared with the scarcity below of vertebrate fossils. There is some resemblance to the Lower Murrees, although strong purple tints are rare or absent.

The strong ridges of hard sandstone form long hill-ranges and are a marked feature of the relief of the country. Being underlain and overlain by softer and more argillaceous beds, the Kamlials, in areas where they are steeply dipping, can be seen at great distances, their jagged sandstone beds rising characteristically from the plain.

Fauna.

They have yielded a fairly rich fauna, which has been examined by G. E. Pilgrim,[1] amongst which are *Conohyus sindiensis*, *Listriodon guptai*, *Hyoboops palaeindicus*, and a species of *Chalicotherium*. The first three species are also found in the Lower Manchars of Sind. Pilgrim[2] thinks, on the evidence of the *Listriodon*, that the age is oldest Vindobonian, if not as old as uppermost Burdigalian.

Messrs. Lahiri and Aiyengar have collected, mainly from the Kamlial outcrops south of the Khair-i-Murat, the following :—

Trilophodon cf. *angustidens*.
Dinotherium indicum.
Dinotherium sp., small species.
Amphicyon sp. cf. *A. shahbazi*.
Hyaenaelurus sp., more advanced than either *H. bugtiensis*, or *H. sulzeri*.
Anthracotherium sp., a large species.

[1] *Rec. Geol. Surv. Ind.*, XLVIII, p. 101, (1917).
[2] *Pal. Ind.*, N. S., Vol. VIII, Mem. No. 4, p. 36, (1926).

Hemimeryx cf. *pusillus.*
Hemimeryx blanfordi.
Listriodon pentapotamiae.
Conohyus cf. *chinjiensis.*

In a joint paper[1] Messrs. Pilgrim and Aiyengar describe the above fauna, which comes from the country south of the Khair-i-Murat between the villages of Sadrial and Phamra Jagir, and note the close relationship with the basal Manchar fauna of Sind.

The Chinji Stage (Siwalik Series).

The type area is Chinji, a village about 17 miles south of Talagang.

Lithology.

The Chinjis are predominantly a clay formation. Anderson estimates the proportion of clay as 70 per cent. The bright colour of the clays is characteristic, brick red being the prevailing tint. The sandstones are of a light colour, and softer than those of the Kamlials. Sometimes bands of magnetite sand form dark coloured bands in the sandstones; this, however, is a feature which is more commonly observed in the Nagris. The sandstones often assume a greenish tint. Frequently, scattered pebbles occur in them; these are usually of quartzite.

The Chinjis are easily recognised, owing to the prevailing brick red colour due to the preponderance of red clay, and also to the sunken relief of the country where they outcrop.

Thickness.

G. E. Pilgrim[2] gives a thickness of 2,300 feet to this stage. R. van Vlek Anderson[3] states that the thickness varies from 1,400 feet in the southern region to about 4,500 feet in the north. West of Kallar Kahar, the thickness of the Chinjis is about 2,600 feet at a maximum, but the stage is attenuated at Kallar Kahar itself. At Chinji, the thickness is about 2,100 feet, according to G. E. Pilgrim,[4] while about nine miles north of Chinji village, the thickness of the Chinjis, as ascertained from the deep borehole put down at Jhatla, is 2,807 feet.[5]

[1] G. E. Pilgrim and N. K. N. Aiyengar, 'The Lower Canine of an Indian Species of Conohyus', *Rec. Geol. Surv. Ind.*, LXI, p. 196, (1928).
[2] *Rec. Geol. Surv. Ind.*, XLIII, Pl. 26, (1913).
[3] *Op. cit.*, p. 686.
[4] *See* section, *Rec. Geol. Surv. Ind.*, XLIII, Pl. 28, (1913).
[5] R. van V. Anderson, *op. cit.*, p. 702.

At Dhulian, W. S. W. of Khaur, the thickness of the Chinjis must be quite 4,000 feet, but the base is uncertain, as it can only be guessed from boring records. At Khaur itself, Pinfold gives a thickness of about 4,000 feet. Near Mianwala north-west of Khaur, the thickness is probably as much as 4,500 feet, but it is difficult to be certain, owing to the possibility that reduplication occurs in this highly folded terrain.

Just as the underlying formations show attenuation along the northern margin of the Salt Range, so also the Chinjis show the same feature.

Fauna and age. The fauna of the Chinji stage has been described by G. E. Pilgrim.[1] It is as follows:—

Hipparion sp.
Palaeoryx sp.
**Dissopsalis carnifex*.
* ,, *ruber*.
**Sivapithecus indicus*.
Palaeosimia rugosidens.
Dryopithecus chinjiensis.
***Listriodon pentapotamiae*.
Amphicyon chinjiensis.
,, *palaeindicus*.
Sivaelurus chinjiensis.
Progiraffa sivalensis.
***Giraffokeryx punjabiensis*.
***Dinotherium pentapotamiae*.
***Trilophodon macrognathus*.
***Hemimeryx pusillus*.
Dorcabune anthracotheroides.
,, *hyaemoschoides*.
Conohyus chinjiensis.
,, *indicus*.
Propotamochoerus salinus.
Lophochoerus exiguus.
Listriodon pentapotamiae.
Dicoryphochoerus chisholmi.
,, *haydeni*.

[1] *Rec. Geol. Surv. Ind.*, XLIII, p. 307, (1913); XLIV, p. 265, (1914); XLV, pp. 1, 226, (1914). *Pal. Ind.*, N. S., Vol. IV, Mem. No. 1, (1911); Vol. VIII, Mem. No. 4, (1926); Vol. XIV, (1927); Vol. XVIII, (1932).

Dicoryphochoerus instabilis.
******Sanitherium cingulatum.*
Protragocerus, 2 spp.
Gazella sp.

In the above list, the species marked* come from the Upper Chinjis, those marked ** are common to both Lower and Upper Chinjis, while that marked *** comes from the basal Chinjis. The horizons of the unmarked species are uncertain.

The chief distinction between the Upper and Lower Chinjis is the first appearance of *Hipparion* in the former.

The list given above is taken from G. E. Pilgrim's papers. A fuller list is given by W. D. Matthew.[1] He notes that the fauna has a distinctly Miocene aspect in such genera as *Listriodon*, in the primitive stage of the antelopes, absence of large giraffoids, of progressive rhinoceroses and chalicotheres, but most especially in the absence, save doubtfully near the top, of *Hipparion*. Matthew regards the fauna as Upper Miocene but at a higher horizon than Pilgrim, who, regards the age as Tortonian. Matthew considers that the appearance of *Hipparion* in the Old World marks the incoming of the Pliocene. He would, therefore, place the Chinji stage in the uppermost Miocene. Both authorities note the close relationships with the fauna of La Grive St. Alban in the Rhone basin.

Mr. Lahiri has collected vertebrate fossils from various localities in the Chinjis, but these have not yet been critically studied by Dr. Pilgrim. Mr. Lahiri recognises *Dinotherium*, *Mastodon* (*sensu lato*), *Giraffokeryx punjabiensis* and *Dicoryphochoerus* sp.

I was fortunate enough to find a single tooth of *Hipparion* in the upper part of the Chinjis, north of Chhumbi village, which is two miles east of Kallar Kahar. The doubts, which Matthew expresses regarding the occurrence of *Hipparion* in the Chinjis, seem therefore unfounded.

The Nagri Stage (Middle Siwaliks).

The Nagri is predominently an arenaceous group, and some of its beds of sandstones attain a thickness of as much as 300 feet.

Lithology.

These massive beds are parted by clays of a light red colour, not so bright as those of the

[1] *Bull. Am. Mus. Nat. Hist.*, LVI, p. 453, (1929).

Chinjis, nor as those of the Dhok Pathan stage above. The sandstones contain abundant scattered pebbles. True conglomerates occur, but pseudo-conglomerate beds are more frequent. The sandstones are of a pale olive green hue, and usually of a medium grain. Mr. Lahiri notes that the interbedded clays are in colour like the reds of the Chinjis in the lower part of the stage, but tend to become orange towards the top, in this respect resembling the Dhok Pathan clays. They are, however, always duller in appearance than those of the stages above or below. Limonitised and silicified fossil wood is of common occurrence, and Mr. Lahiri thinks that its presence is a fairly constant character recognised over large areas. Vertebrate remains are somewhat rare in this stage.

Thickness.

In the country east of Kallar Kahar, there is a good section through the Middle and Upper Siwaliks in the Sauj stream about two to four miles south of Bhaun. The total thickness of the Middle Siwaliks in this section is 4,560 feet, of which the Nagris constitute a thickness of 2,460 feet, and the Dhok Pathans 2,100 feet. In the section between Dhok Pathan village and the Dhulian anticline on the road to Pindi Gheb, the thickness of the Nagris alone is about 5,300 feet, *i.e.*, more than double the thickness of the whole Middle Siwaliks south of Bhaun on the northern flanks of the Salt Range. Here again, we find clear evidence of attenuation in the Salt Range area. Mr. Lahiri again estimates the thickness of the Nagris as 5,300 feet in the country between the Indus and the high road from Basal through Pindi Gheb to Talagang.

The Nagris are distributed mainly about the flanks of the Soan geosyncline, the middle of which is occupied by beds belonging to the Dhok Pathan stage. Their lower boundary is generally easily mapped, since the passage from the massive sandstones of the Nagris to the argillaceous Chinjis is usually fairly sharp. There are usually 100 feet or so of passage beds, in which the proportion of clay to sandstone is about equal. But in the country north west of Pindi Gheb near Kharpa village, the passage beds between the Chinjis and the Nagris are as much as 500 feet thick. These beds have been included in the Chinjis. In the massive sandstones, dogger concretions sometimes occur. Dark bands containing abundant magnetite are fairly common. The Dhok Pathan–Nagri boundary is marked by inconstant beds of conglomerate. These conglomerates must be regarded as the base of the Dhok Pathan

stage, and will be described under that head. It may be remarked however that, since they are not constant, but fade out along the strike into sandstone in several localities, the main distinction between the Dhok Pathan stage and the Nagri stage is the general lithology; the Dhok Pȧthans being a formation with 50 per cent. of clay, while the Nagris are perhaps 80 to 85 per cent. sandstone. The colour of the Nagris differs also strongly from that of the Dhok Pathans; in the latter stage, the sandstones are a gleaming white, and the clays often a bright orange.

Fauna.

The fauna of the Nagris has been described by G. E. Pilgrim in the same papers as were cited above for the Chinjis. The fauna is as follows:—

Hipparion cf. *theobaldi.*
Aceratherim cf. *perimense.*
Antelopes, several species.
Large giraffoid (earliest occurrence).
Giraffokeryx sp.
Dorcabune nagrii.
Dorcatherium majus.
" *minus.*
Conohyus indicus.
Propotamochoerus salinus.
Lophochoerus nagrii.
" *himalayensis.*
Sus advena.
Lycyaena sp.
Hemimeryx pusillus.
Dryopithecus giganteus.
" *punjabiensis.*
Sivapithecus orientalis.
" *himalayensis.*
Palaeopithecus sylvaticus.
Hylopithecus hysudricus.

In this fauna, the abundance of *Hipparion,* the first appearance of large giraffes, and the absence of *Listriodon* are features which seem to point to a late Tertiary age. Pilgrim places the Nagri horizon in the Sarmatian, but W. D. Matthew thinks that *Hipparion* could not have made its appearance earlier than Pontian. In that case, we might feel disposed to place both the Upper Chinjis and the Nagris in the Pontian.

The Dhok Pathan Stage (Middle Siwaliks).

G. E. Pilgrim describes the Dhok Pathan stage[1] as one of deep orange and red clays and grey sandstones, with occasional true conglomerate bands. The Upper Siwaliks pass down abruptly into these beds. More often, the sandstones are a gleaming white. The clay beds may occasionally take on brown or drab tints, but the most frequent colours are red and orange.

North of Dhok Talian near the road between Chakwal and Khewra, and in the stream east of the road, there is a section through the Dhok Pathan stage, which gives a clear idea of the facies. It is as follows, in descending order :—

Section at Dhok Talian.

	Feet.
Upper Siwalik basal conglomerate	*not measured*
Screes with ill seen, orange clays and soft sandstones	41
Red and orange clay	18
White sandstone	11
Orange clay	12
White, micaceous sandstone	20
Orange clays, *ill seen*	12
Sandstones, *ill seen*	14
Beds poorly seen, largely orange and drab clays with orange clays above	212
Greenish white, micaceous sandstone with orange clays above	18
Bright orange clays	20
Sandstones with pebbles and limonite nodules, in places conglomeratic	65
Orange and light red clays	47
Greenish white sandstone	33
Orange and drab clays	41
Greenish white sandstones	31
Orange clays with thin sandstone partings	68
Greenish white sandstones with some bands of pseudo-conglomerate	72
Bright orange clays	28
Sandstones, soft, greenish white	9
Orange clays with sandstone band	74
White, soft sandstones	20
Drab and brown clay	15
Greenish white, soft sandstones	82
Orange and brown clays	68
Sandstones	8
Orange clay	22
Sandstone	3
Clay	7
Sandstone	6
Orange clay	25
Soft, greenish white sandstone	106
Tawny red to orange clays with bands of pseudo-conglomerate and sandstone bands near top	195
Massive, coarse sandstones with pebbles and limonite nodules	238

[1] *Rec. Geol. Surv. Ind.*, XLIII, p. 274, (1913).

	Feet.
Orange red to brown and drab clay	16
Greenish white, soft sandstone	19
Orange to red clays with thin bands of sandstone and pseudo-conglomerate	41
Soft, greenish white sandstone	41
Reddish, dull coloured clays	16
Greenish white, soft sandstone	25
Light orange to red clays	33
Light buff sandstones with a 3-ft. band of red clay in middle . .	27
Brown to red clay with thin beds of sandstone	85

At this point, the road crosses the stream from which this section was taken. The mileposts show that the spot is $21\frac{1}{4}$ miles from Pind Dadan Khan. On the one inch to one mile map sheet No. 43 D/13, the height 1,744 is marked upon the map ; this serves to show the exact place. Below this, the beds have the appearance of Nagris. The thickness of the Dhok Pathan stage here is 2,004 feet.

Thickness.

In the Sauj *kas* south of Bhaun, which is some 13 miles west by north of Dhok Talian, the thickness of the Dhok Pathans was calculated by Mr. H. M. Lahiri and myself to be 2,100 feet.

In the Soan river area near Dhok Pathan, there are probably not more than 1,000 feet of beds exposed referable to the Dhok Pathan stage, but the top is not seen, and this measurement only comprises the basal beds from the Nagri-Dhok Pathan boundary to the centre of the Soan geosyncline.

In the west of the area, the Dhok Pathans thicken somewhat, but the axis of the geosyncline is occupied by this stage, so that the thickness cannot be estimated.

Lithology.

The Dhok Pathans rest upon the Nagris with a basal conglomerate, which however is in many sections absent. It is well developed north of Mehro Pilo, a village on the road from Chakwal to Nila in Jhelum district. It is missing or at least not conspicuous (for there are some thin beds of conglomerate at many horizons through the Middle Siwaliks) in the section in the Sauj stream south of Bhaun. The two places named above are on the south side of Soan geosyncline. On the north side of the geosyncline, beginning from the eastern boundary, the conglomerate is richly developed into beds over 100 feet thick near Gandakas and Mahluwala villages north of Nila. From this point, it thins down westward, and is inconspicuous north of Mathrala (a village from the vicinity of which many of the Dhok Pathan type specimens were collected by G. E.

Pilgrim). North of Dhok Pathan itself, there is no conspicuous band of conglomerate, and there is a passage from the orange clays and cream white and greenish sandstones of the Dhok Pathans to the massive sandstones of the Nagris. In the country west of Dhok Pathan, the base of the Dhok Pathans around the flanks of the Dhulian dome is somewhat indefinite by reason of the absence or inconspicuousness of conglomerate beds. But further west near Nakka Ghulam Shah and Nalhad, Mr. Lahiri notes that the basal conglomerate is again developed and forms a well marked horizon, and even outcrops as low hilly ridges.

Lateral change into a conglomerate facies.

The Dhok Pathans above this inconstant basal conglomerate are, as can be seen from the section near Dhok Talian described in detail above, fairly free from conglomerate beds. It is surprising then to find that when traced laterally to the country north of Tamman, south of Nalhad, and near Makhad, they develop thick beds of true conglomerate, and even boulders. Mr. Lahiri notes that the white sandstones north of Tamman are seen to pass laterally into very thick conglomerate beds near Trap Rest House. The pebbles are as much as four inches in diameter and are composed of hornblende-gneiss and quartzite. These conglomerates are interbedded with coarse sandstone with muscovite plates. I counted six bands of conglomerate in a cliff section about 30 feet high.

On the northern flank of the Soan geosyncline, between Chhab and Jhamat, in the most southerly railway tunnel north of Chhab, there are 40 feet of conglomerates, above and below which are the red and orange clays and white sandstones so typical of the Dhok Pathans. South of Uchhri railway station, again, there are exposures of Dhok Pathans also containing numerous conglomerate beds, associated with sandstones and clays of the typical appearance. When traced eastwards along the strike from the Jhamat area, these conglomerate beds degenerate, according to Mr. Lahiri, into pebbly sandstones, and finally into true sandstones with only a few scattered pebbles. At Makhad on the Indus bank again, the Dhok Pathans, which are here horizontal, contain boulder beds and conglomerates.

Detailed mapping on the scale of one inch to one mile has brought out the fact that the change in facies of the Dhok Pathans is not due to any overlap of a newer stage, but is actually due to lateral change. But former geologists, who had not the opportunity of

detailed mapping, have assumed that the conglomerate bearing beds belong to a newer stage—the Upper Siwaliks. A. B. Wynne[1] has shown the country around Makhad as Upper Siwalik, while that around Dhok Pathan is shown as Lower Siwalik. He remarks that 'these conglomerates are inconstant', and again 'the conglomerate is in greatest force near the large rivers......away from the large rivers, as in the Soan basin, conglomerate beds, though less prominent, still appear'. W. Waagen[2] describes these conglomerates along the Indus near Makhad and west of Chhab as 'conformable conglomerates' resting upon the 'Dungote Sandstone'. Waagen's Dungote sandstone corresponds with the Nagri, and he notes that they are 2,000 feet thick in the type area near the gates of the Salt Range at Kalabagh. It has been noted above that the Nagris are 2,460 feet thick south of Bhaun. Mr. Lahiri regards them as about 3,000 feet thick on the north flank of the Salt Range, south of Tamman. The thickness given by Waagen, although slightly less, is sufficiently close. Waagen does not suggest what is the age of the 'conformable conglomerate'. G. E. Pilgrim[3] refers the conglomerates of Makhad to the Upper Siwaliks, while instancing the occurrence of a metatarsal bone of the Upper Siwalik genus *Sivatherium* from the Makhad conglomerates. But

Age of the Makhad conglomerates.

it does not seem to me possible to distinguish this metatarsal from a metatarsal of *Hydaspitherium* in the present state of our knowledge of the Indian Giraffidae. Moreover, a molar fragment from the Dhok Pathan stage of Asnot was doubtfully referred by Pilgrim[4] to the genus *Sivatherium*, and it is possible that *Sivatherium* itself extends downwards to the Dhok Pathans. On the other hand, it seems more reasonable to suppose that both the Asnot specimen and that from Makhad really belong to *Hydaspitherium* and not to *Sivatherium*. E. S. Pinfold[5] considers that the conglomerates near Injra and Makhad are Upper Siwalik. He says that there is an increase in the conglomeratic character of the Middle Siwaliks, *as we pass upwards*. He adds that the conglomerates overlap many of the older rocks. I have shown above that Mr. Lahiri and

[1] *Rec. Geol. Surv. Ind.*, X, p. 121, (1877).
[2] *Ibid.*, XVII, p. 118, (1884).
[3] *Rec. Geol. Surv. Ind.*, XL, p. 192, (1910); XLIII, Pl. 26, (1913).
[4] *Pal. Ind.*, N. S., Vol. IV, p. 22, footnote, (1911).
[5] *Rec. Geol. Surv. Ind.*, XLIX, p. 156, (1918).

I have, in the course of detailed field mapping, been led to disagree with this opinion, and that we consider that the change is a lateral passage and not a vertical one.

R. van V. Anderson[1] inclines to the opinion that the beds near the Indus (Makhad-Chhab area) are Upper Siwaliks, but he is somewhat cautious, thinking that in several sections in other parts some Middle Siwaliks have been included in the Upper. He also groups the Middle and Upper Siwaliks in his map. It would seem from one passage on page 687 of Anderson's paper that he included the Dhok Pathan stage in the Upper Siwalik. He says—

> 'Owing to the lithologic variation and the difficulty of recognising a consistent line of separation between the Middle and Upper Siwalik, it is impossible to give reliable figures as to the comparative thicknesses of these divisions in different areas. For instance, in the north central portion of the Potwar, the Middle Siwalik comprises mainly sandstone from 5,000 feet thick (Dhulian anticline)........'

This last passage seems to indicate that the Nagri sandstone, which I have stated is 5,300 feet thick near Dhulian, is taken as the Middle Siwalik and the beds above, including the type area at Dhok Pathan village and rest house, of the Dhok Pathan stage, are regarded as Upper Siwalik. If these beds were included in the Middle Siwalik by Anderson, his estimate of 5,000 feet would be considerably below the mark, and the statement that the Middle Siwalik comprises mainly sandstone would be incorrect.

Included in the Upper Siwaliks by D. N. Wadia.

D. N. Wadia[2] has included in his Upper Siwaliks those rocks which are, in the present memoir, mapped as Dhok Pathans. He states that his Upper Siwaliks comprise two stages, a lower one of red earthy clays and coarse pebbly sandstones, and an upper one,—2,000 to 3,000 feet thick—mainly conglomerate. The lower stage would appear to be homotaxial with the Dhok Pathans of Attock district. Wadia's map again, when aligned with that accompanying this memoir, shows that the Dhok Pathans have been included by him in the Upper Siwaliks.

Wadia gives a list of the fauna from the Upper Siwaliks on page 344 of his memoir. This fauna contains such typical Upper Siwalik species as *Equus sivalensis*, *Hyaena colvini*, and *Hyaena felina*, which point to the Boulder Conglomerate stage (uppermost stage of Upper Siwaliks). But amongst the list are more typical Dhok Pathan

[1] *Op. cit.*, p. 688.
[2] *Mem. Geol. Surv. Ind.*, LI, Pt. 2, p. 285 and Pl. 11, (1928).

species such as *Hipparion antelopinum*, *H. punjabiense*, *H. theobaldi*, *Hydaspitherium* sp. and *Vishnutherium* sp. The absence of *Sivatherium*, the poverty of *Bovidae*, the abundance of *Hipparion*, all these point to the Dhok Pathan stage, and would seem to indicate that there are two faunas, an upper of Upper Siwalik age with *Equus* and *Hyaena*, and a lower with abundant *Hipparion* and *Hydaspitherium*, this lower stage being of Dhok Pathan age.

It would appear that, wherever the Nagri-Dhok Pathan conglomerate is mappable, Wadia has taken this as a boundary between the Middle and Upper Siwaliks. In the present memoir, however, it has been thought advisable to place the Dhok Pathans in the Middle Siwaliks as their upper subdivision, following Pilgrim's original scheme. If however the age of the Dhok Pathans should prove to be Middle Pliocene, as Matthew thinks, it may seem advisable afterwards to include them in the upper division. The question is, however, one that does not seriously affect either Mr. Wadia's map or my own, if our different treatment of the Dhok Pathans is kept in view.

Wadia thinks that overlap may account for the replacement along the strike of Dhok Pathan stage rocks by Upper Siwalik rocks. Such overlap is mentioned on page 285 of his memoir. As regards this, I am not able to express an opinion, since I have not visited the area mapped by him except in a few localities. If overlap exists, however, it does not appear to bring in Upper Siwalik rocks in the Soan geosyncline in the area now shown in the map accompanying this memoir. He thinks that the Tatrot stage of the Upper Siwaliks may replace the Dhok Pathan stage by overlap. This stage occurs near Bhaun, but I am convinced that it does not occur in that part of the Soan geosyncline which lies between Mehro Pilo and Nila, nor in the country adjoining the villages of Dhok Pathan, Rupwal, Kot Sarang, Tamman, Nalhad, Chhab, and Makhad.

Fauna.

The fauna of the Dhok Pathans has been described in great detail by R. Lydekker[1] and G. E. Pilgrim,[2] and it is unnecessary for me to give a list of the species found. Pilgrim regards the Dhok Pathans as homo-

[1] *Pal. Ind.*, Ser. X, Vols. I to IV, (1874-1887).

[2] *Rec. Geol. Surv. Ind.*, XXXVII, p. 139, (1908); XL, p. 63, (1910); XI, p. 185, (1910): XLIII, p. 264, (1913); XLIV, p. 225, (1914); XLIV, p. 265, (1914); XLV, p. 1, (1915): XLV, p. 138, (1915); XLV, p. 226, (1915); LXI, p. 196, (1928). *Pal. Ind.*, N. S., Vol. IV, Mem. No. 1, (1911); Vol. VIII, Mem. No. 4, (1926); Vol. XVIII, (1932).

taxial with the Pikermi fauna, but Matthew[1] thinks that the Giraffidæ (*Brahmatherium* and *Hydaspitherium*) of the Dhok Pathans are distinctly more advanced than anything found in Pikermi, Samos, Maragha, or China. They are, however, less specialised than the Upper Siwalik forms *Sivatherium* and *Indratherium*. He also thinks that the Dhok Pathan forms *Hipparion theobaldi* and *H. antelopinum* are more highly specialised forms than the Hipparions from Pikermi, Samos, and China. Summarising the evidence, Matthew thinks that the Dhok Pathan fauna may be as late as Middle Pliocene. G. E. Pilgrim has hitherto supported a direct correlation with the Pikermi fauna, and a Pontian age.

A fair amount of material has been collected from the Dhok Pathan stage by Mr. Lahiri and myself, but no new species were added to the list.

The Upper Siwaliks.

A small patch of rocks have been mapped as Upper Siwaliks in the south-east corner of the map accompanying this memoir. This is the area near Bhaun where Mr. Vinayak Rao [2] first discovered Upper Siwalik rocks. He estimated the thickness of these rocks to be 2,000 feet, and collected vertebrate specimens from them, which show that they belong to the Tatrot or lowermost sub-stage of the Upper Siwaliks. The Tatrot rocks are friable, brown sandstones with interbedded, drab and pale brown clays and conglomerates, and lithologically closely resemble the Upper Siwaliks of Bhaun. The Bhaun rocks lie in a synclinal basin, narrow and long, aligned in an E.–W. direction. They can be traced east of Bhaun to north of Dhok Talian, and finally into the country north-west of the Bakrala hill in Jhelum district.

Bhaun section.

In the section in the Sauj stream south of Bhaun, the basal bed of the Upper Siwaliks is a hard, pebbly brown sandstone grading to a conglomerate, and overlain by brown sandstone. The Upper Siwalik sandstones of this section are not white as are those of the Dhok Pathans below, but vary from cream to buff and brown. They are overlain by brown clay rather like that of the older alluvium, but this clay has subordinate beds of buff or pink sandstone, and has a dip, while the older alluvium near Bhaun is horizontal. In the section north

[1] *Op. cit.*, pp. 450-452.
[2] *Rec. Geol. Surv. Ind.*, XLIII, p. 277, (1913).

of Dhok Talian, the Upper Siwaliks rest with a basal conglomerate about 100 feet thick upon the Dhok Pathans. This conglomerate contains boulders about the size of tennis balls, among which are pebbles of a pink, graphic granite recalling the granite of Jalor[1] and other neighbouring areas in Western Rajputana. Similar boulders were found by F. R. C. Reed, H. M. Lahiri, and myself[2] in the Talchir boulder bed at the base of the Speckled Sandstone in the Salt Range. I think that there is no doubt that this specimen of pink graphic granite in the basal conglomerate of the Upper Siwaliks at Dhok Talian came from the Talchir boulder bed in the Salt Range, and it indicates that the Salt Range was an elevated area, undergoing severe denudation at the commencement of Upper Siwalik times.

Talchir boulder in basal conglomerate.

Above these basal conglomerates are soft, brown sandstones with abundant included pebbles. These rocks are interbedded with clays of a brown or drab colour resembling the alluvial clays rather than those of the Dhok Pathans.

The Upper Siwaliks of Bhaun and Dhok Talian are lithologically of the same appearance as those of the Pabbi hills in Gujarat district, and as the Upper Siwaliks south of the Salt Range at Jalalpur Sharif in Jhelum district.

Age of Tatrot stage.

G. E. Pilgrim regards the Tatrot stage, to which these beds are referred, as Lower Pliocene. But, as we have seen above, W. D. Matthew considers that the Pontian age ascribed to the Dhok Pathans is too low. In that case, the raising of the Dhok Pathans to a higher level would involve the raising of the Tatrots also. It may be that the Upper Siwaliks in their highest stage (the boulder conglomerates) are entirely Pleistocene, and that the two stages below, the Pinjor and the Tatrot, are Upper and Middle Pliocene respectively, the Dhok Pathans being Lower Pliocene.

To the south-east of Jaba and Uchhri station on the railway from Jand junction to Mianwali, Mr. Lahiri noticed some banded clays overlying Dhok Pathan sandstones and conglomerates. He thinks that there is a lithological resemblance to some of the clays of the Upper Siwaliks in the Bhaun section but, in the absence of fossil evidence, he cannot correlate them with any certainty.

[1] *Rec. Geol. Surv. Ind.*, LX, p. 115, (1927).

[2] *Ibid.*, LXII, p. 418, (1930). The registered number of the granite boulder from Dhok Talian, in the Geological Survey of India collection is 43/919 (slide No. =21833).

CHAPTER V.

SUB-RECENT AND RECENT FORMATIONS.

Boulder Conglomerate and Gravel.

Sub-Recent boulder beds and conglomerates are common all over the district. The streams north of the Kala Chitta near Jabbi about 10 miles north-west of Fatehjang, cut through thick beds of gravel and boulders. In this area also, the small rounded hillocks lying near the base of the Kala Chitta are composed of gravel. There is much gravel north of Burhan and Hasan Abdal. In many tracts in the Potwar, patches of gravel and coarse boulders cover the ground. These beds are probably at or near the base of the older alluvium, but it is not to be supposed that all the gravel deposits are of this age. The older alluvium rests with a basal conglomerate upon the Siwaliks in many sections, as for instance, in the Ghambir river south-west of Dhrabi. Conglomerates and thin sands occur near the Khair-i-Murat. Mr. H. M. Lahiri reports that the alluvium becomes more and more gravelly in type as one approaches the Indus.

Older Alluvium.

The older alluvium consists of buff and brown silts, sands, and clays, with bands of coarse gravel. North of Burhan, it is cut by the *nalas* to depths of 70 feet. These *nalas* have almost perpendicular sides, and the whole country between Burhan and Lawrencepur, and north of Hasan Abdal is deeply intersected by these streamlets, locally known as *kudehra*. Other tracts of country which are deeply intersected by these *kudehras* are (1) between Mehro Pilo and Nila in the Chakwal tahsil, Jhelum district; (2) north of Dhrabi in the same tahsil; (3) south and east of Kot Sarang in Talagang tahsil.

Contrasting with these tracts of deeply excavated country are areas where the streams have shallow banks, as between Campbellpur and Hazro and Lawrencepur, and in the country east of Nila.

Recent warping probably accounts for the alternation of deeply excavated with flat country with shallow stream beds.

Travertine.

Deposits of travertine occur near Dher Dhok and Hatar to the N.N.E. and north-east of Fatehjang. They form small hillocks. North of the Khair-i-Murat, Mr. Lahiri reports that the streams contain travertine deposits; the travertine also not infrequently forms low isolated mounds. He also notes the occurrence of travertine near the sharp southerly bend of the Indus, where it enters the Kala Chitta.

North of the Salt Range, close to the outcrop of Hill Limestone, the streams have deposits of travertine. There are travertine deposits at Kallar Kahar, and at Choa Saidan Shah in the Jhelum district.

Erratic Blocks, Moraine Material.

The erratic blocks of the Punjab have already been discussed in a former paper by me.[1] In this paper full references are given to earlier literature, including the controversy between A. B. Wynne and W. Theobald upon this subject.

According to A. B. Wynne, there is at Nurpur Karmalia, a village $6\frac{1}{2}$ miles W.N.W. of Campbellpur, a group of erratic blocks, the largest of which is of granite, and has a girth of 50 feet and a height of six to eight feet. A second, near by, has a girth of $48\frac{1}{2}$ feet with a height of $12\frac{1}{2}$ feet and is of basalt. Other erratics are described from Hatti, ten miles north-east of Campbellpur. These erratic blocks lie on alluvium.

I found two erratic blocks of gneissose granite half a mile north-west of Bura village, which is four miles east of Campbellpur. The dimensions were :—height 9 feet, length 10 feet, width 6 feet, and height 6 feet, length 7 feet, width 6 feet. There was also a large boulder of Hazara slate lying close by. All these blocks rested upon Kioto limestone and not on alluvium.

At Jand, there are several places where erratic blocks are found. Two miles from Jand on the road to Kohat, on the south side of the road, where the footpath from Bhandarbara joins it, there is a group of erratics, which have been described by Wynne and Theobald.

The largest, a block of coarse granite, is 14 feet long, 9 feet wide, and 4 feet high, the base being buried in alluvium. Other boulders of syenite, fine-grained granite, schist, and dark slate are also there.

[1] 'The Erratics of the Punjab', *Rec. Geol. Surv. Ind.*, LXI, p. 327, (1929).

The alluvium is here thin, and is underlain by the Murree series, which outcrop all round.

There is an erratic block of granite gneiss, which is situated three-quarters of a mile west by north from Jand Railway station. This block is $5\frac{1}{2}$ feet long by 4 feet wide. It rests upon coarse, unsorted sand and gravel with boulders. Another smaller block lies upon this sand about one furlong nearer to Jand.

North of Jand station, there are sand hills with scattered small boulders of granite gneiss upon the surface. This is about one furlong north of the railway station.

On the road from Jand to Gulial, near the Resh *nala*, there are broken pieces of gneiss, evidently the remains of an erratic block.

The erratics are not oriented in any special direction notwithstanding the assertion of W. Theobald [1] that they are aligned in an E.-W. direction.

The sandy deposit upon which these erratics rest contains abundant boulders, and has the unsorted appearance which suggests a glacial outburst.

One-quarter of a mile north-west of Kharpa village, five miles north-west of Pindi Gheb, three large boulders of travertine rest upon Chinji rocks. The largest of these is $7\frac{1}{2}$ feet high, 5 feet broad, and 12 feet long.

Mr. Lahiri reports that a block of Hill Limestone, measuring 10 feet by 8 feet by 6 feet, was found in the bed of the Nara stream near the junction with the Indus. There was another block of Nummulite Shale, measuring 5 feet by 4 feet by 1 foot. He thinks they should be grouped with the other erratics.

The most southerly erratics yet found were observed by Mr. H. M. Lahiri, about one mile E.N.E. of Tut, a village about 12 miles W.S.W. of Pindi Gheb. They are seen on a track running east to Ama Shaba ki Ban. The largest was $7\frac{1}{2}$ feet by 5 feet by 2 feet. The rock is a gneissose granite of a type resembling the granite of the Himalayas.

The most interesting occurrence is, however, the moraine-like deposit in the valley lying between the Kawa Gar and the low ridge of Hill Limestone to the north; this valley contains moraine material east of Jassian, a village one mile south of Campbellpur. This moraine deposit continues to cover the valley floor to a distance

[1] *Rec. Geol. Surv. Ind.*, X, p. 142, (1877).

about three miles east by south of Jassian. The deposit consists of mixed boulders of Attock slate, Giumal limestone, Nummulitic Limestone, and occasional gneissic boulders. One of these measured 3 feet by 2 feet by 2 feet. The condition of the deposit is unsorted, the boulders lying in a mixture of sand and gravel.

I have suggested in the paper above quoted that the cause of these erratics is catastrophic. There is no trace of glacial erosion, nor any evidence of a glacial period in the Attock district. It seems wiser to regard these deposits as due to a sudden catastrophic outburst of glacial mud and water, rather than to the slow action of glaciers. Such outbursts, known as *shwas*, are not uncommon in the higher Himalayas, and we have only to suppose that a catastrophe on a grander scale than anything within historical memory happened at some prehistoric period, and thus brought these erratic blocks into their present position.

From the presence of Attock or Hazara slate and of gneissose granite of the Himalayan type, it is reasonable to suppose that these blocks were transported from the north.

It is reasonable to suppose that the flood which brought these erratic blocks to their present position was one in the Indus. In 1841, a great flood, due to the bursting of a dam caused by a landslip in Gor near Bunji, that is south of Gilgit, caused the Indus to flood the town of Tarbela in Hazara district ; the river is described as coming down in a wall of mud.[1]

Newer Alluvium.

There is not much to be said regarding the newer alluvium. It occupies the low lying land around river banks, and is highly fertile and contains abundance of water.

North of Campbellpur, north of the road from Lahore to Peshawar, a low lying tract between the Grand Trunk road and the Indus is known as the Chhachh plain. For the most part highly fertile, there are some badly drained patches in the Chhachh, where efflorescent salt (*kallar*) has rendered the land sterile. This efflorescent salt is the usual mixture of chloride, carbonate, and sulphate of soda. In the Chhachh, the chloride was subordinate as compared with the other two salts in the specimens collected.

[1] *See* A. Cunningham, 'Ladakh, Physical, Statistical, and Historical', London, (1854) ; and T. G. Longstaff, 'Glacier Exploration in the Eastern Karakoram', *Geogr. Journ.*, XXXV, p. 648, (1910).

CHAPTER VI.

THE STRUCTURE OF THE KALA CHITTA HILLS AND THE POTWAR PLATEAU.

General Remarks.

The general structure of the Attock district has been summarised by E. S. Pinfold,[1] who recognises six regions :—(1) the Kala Chitta hills ; (2) the isoclinal belt along the southern margin of the Kala Chitta ; (3) the fault zone ; (4) the anticlinal zone ; (5) the Soan geosyncline ; and (6) the Salt Range. B. R. MacKay, as quoted by R. van V. Anderson,[2] recognises similar belts of folding, *viz.* :—(1) the isoclinal zone, in which he includes the Kala Chitta, and the piedmont region along its southern margin ; (2) the fault zone ; (3) the anticlinal zone ; (4) the Soan synclinorium ; (5) the terrace zone, that is the flat terrace on the south flank of the Soan geosyncline ; (6) the Salt Range monoclinal zone ; and (7) the Salt Range anticlinorium.

In order to explain the structure, I propose to describe (1) sections through the Kheramar hill, the Kawa Gar hill, and other areas north of the Kala Chitta ; (2) sections through the Kala Chitta ; (3) sections in the isoclinal and fault belt south of the Kala Chitta ; (4) sections through the anticlinal belt ; and (5) sections through the Soan geosyncline, including B. R. MacKay's terrace zone. Sections in the Salt Range do not fall within the scope of this memoir.

Sections through Certain Hills North of the Kala Chitta.

Hasan Abdal Hill.—A section through this hill is given as a text-figure on page 217 of *Memoirs, Geological Survey of India,* XXVI. The top of the hill is of Hill or Laki limestone, beneath which there are about 60 feet of nodular yellowish limestone with *Echinolampas* cf. *lepadiformis.* Below this again is the Ferruginous Pisolite, probably of basal Laki age. This rests upon the Kioto (formerly called Trias) limestone, and the Giumal-Spiti shale unit is absent,

[1] *Rec. Geol. Surv. Ind.,* XLIX, p. 140, (1918).
[2] R. van V. Anderson, *op. cit.,* p. 691.

except along the south-west margin of the hill; thus the Giumals do not appear in the section. The absence of the Giumals may possibly be due to shearing; the formation being less competent than either the Hill or Kioto limestone. The Wah hill is entirely of Kioto limestone; the group of small hills west of Wah are mainly nummulitic limestone, and the structure does not need comment.

Kheramar Hill.—A section through the Kheramar hill is given in Plate 13, fig. 1. The section is on a line running N.N.W. and passing through Jallo village. The rocks are Hill and Kioto limestone, the Giumal-Spiti shale unit being absent. The structure is fan-wise; the dips are more overturned on the southern flank of the range. The fan-shaped anticlinorium is typical of the Kheramar, the Kawa Gar and the Kala Chitta.

Kawa Gar.—This fan-shaped anticlinorium structure is again shown in Plate 13, figs. 2 and 3, through the Kawa Gar range. The section in fig. 2 is drawn from a point about a quarter of a mile west of Daurdad village to Bahadur village, in the eastern termination of the Kawa Gar. Here the fan structure is again obvious, and the rocks are Kioto and Giumal series.

Another section through the Kawa Gar on a line passing due south from a point a quarter of a mile east of Pind Trer village, is shown in fig. 3. The fan-shaped anticlinorium is still more clearly seen, the Giumal bands giving the key to the structure. The whole of the Kawa Gar is on this plan; on the north of the range the dips are southerly, and on the south of the range they are northerly.

In the small hills east of Campbellpur, the structure is not apparent, since the exposures are too small to show more than monoclinal dips as a rule.

Attock Hill, and other hills of Attock slate.—Attock Hill shows steep or vertical dips; the strike is east to west or east by south to west by north; the slates are much crushed. The two small hills near Kamra show dips to the S.S.W. at steep angles or vertical dips with the same strike. The dips of the Attock slate north of Burhan are generally steep to the N.N.W.

Nowhere in the Attock district are the slates seen in contact with the Kiotos, but the section in C. S. Middlemiss' 'Geology of Hazara'[1] shows clearly that where the Infra-Trias or the Kioto ('Trias')

[1] *Mem. Geol. Surv. Ind.*, XXVI, Fig. 1, (1896).

series rests upon the slates, there is strong discordance. We may assume, as a working hypothesis, that in Attock district, the Kiotos rest directly and with discordance upon the Attock slates, since, if we draw a line running south-west to north-east through the south-eastern margin of Sirban Hill overlooking Abbottabad in Hazara, then there is no development of Infra-Trias to the south-east of that line, while there is invariably Infra-Trias to the north-west of the line. The Infra-Trias has a limited extension, and the Kiotos rest directly upon the Attock slate in that part of Hazara which is in continuity with the strike of the Kheramar, Kawa Gar and Kala Chitta. Further, it may be argued that if the Infra-Trias were present in the Attock district, it would surely be brought up in the anticlinal cores of the Kala Chitta, since it is mainly a hard limestone. But it may be supposed that the Attock slates, being an incompetent formation, would not be brought up in the anticlinal cores; the slates might act as a lubricant, and the hard rocks above the slates might be folded by *décollement,* as in the case of the Jura Mountains.

Sections through the Kala Chitta.

The structure of the Kala Chitta will be examined by considering sections across the range first in the eastern part and then at different points along the range proceeding westward.

Plate 13, fig. 4, shows a section from Dhok Baloch village to Gadowala village, about $4\frac{1}{4}$ miles north of Fatehjang. The structure is still the anticlinorium, but is isoclinal and not fan-shape. Probably the presence of the Chharat series and the Murree rocks, which are softer on the whole than the limestones of the Laki or Kioto series, has led to the development of isoclinal in preference to fan structure.

The fan structure is, however, slightly developed in the section shown in Plate 14, fig. 5. This section is drawn from a spot $3\frac{1}{2}$ miles distant from Akhori Forest Bungalow, on the forest road, southwards for two miles in the direction of Kutehra village. There is a distinct tendency to overturning in the northerly dips.

Plate 14, fig. 6, is drawn from Chetuwali Ban ($1\frac{1}{2}$ miles from Akhori on the Fatehjang road) to a spot at the second milepost on the forest road from Akhori Forest Bungalow to Jabbi. The fan-structure is beautifully developed in this section.

In the Kala Chitta between Akhori Forest Bungalow and the railway, there are six transverse sections in Sir Edwin Pascoe's memoir.[1] These are marked *a*, *b*, *c*, *d*, *e* and *f*, section *a* being the most westerly and so in order to *f*, the most easterly. Sections *c* and *d* show on the northern half a slight tendency to fan structure, while in the southern half the dips are overturned, and the Kala Chitta suite of rocks (Laki limestone, Giumal rocks, Kioto limestone) abuts on the Chharat-Murree suite by a reverse boundary fault. The same boundary fault is shown in sections *a* and *b*, and in the central Kala Chitta there is a marked bottle-shaped syncline of Laki limestone, while the structure of the Kala Chitta is here a roof-shaped anticlinorium as opposed to the fan-shaped anticlinorium of sections to the east.

Plate 14, fig. 7, gives a section through the northern half of the Kala Chitta from Dheri Langhal village in a S.S.W. direction to the Jabbiwala Kas stream where it bends round from an E.S.E. course to a N.N.E. course. The structure is the anticlinorium of a normal type.

In Plate 14, fig. 8, a section through the southern part of the Kala Chitta is shown. The section runs to the N.N.E. through Kali Dilli village. The boundary fault separating the Chharat-Murree suite of rocks from the Laki-Giumal-Kioto suite is here shown. The structure in the Kala Chitta is fan-wise.

Plate 15, figs. 9 and 10, show two sections by Mr. H. M. Lahiri across the Kala Chitta hills. Fig. 9 runs E.N.E. from Tali Dhok village, through the Kala Chitta. The reversed fault on the south of the range is shown, and the structure of the range itself is fan-shape. In this section, the Kioto limestone appears to have a thickness of about 1,600 feet. Fig. 10 is a N.-S. section through Sujhanda village, and passing southwards to the west of Chattu-mola Banda. In this section, the structure is a combination of the fan and roof-shaped anticlinorium, and north of Suihanda the Kioto limestone appears to be about 1,600 feet thick.

In all these sections through the Kala Chitta, the rocks of the main range consist of Kiotos of a thickness not exceeding 1,600 feet, Giumal and Spiti shale rocks not exceeding 320 feet in thickness, and Laki limestone with a thickness of about 1,650 to 2,000 feet.

[1] *Mem. Geol. Surv. Ind.*, XL, Pt. 3, Pls. 74, 75 and 76, (1920).

Décollement of the Kala Chitta.

The total thickness of the Kala Chitta suite of rocks is, therefore, only 4,000 feet or less, but no older rocks are anywhere brought up to the surface in the anticlinal cores. Instead, the sequence from Laki to Kioto is constantly repeated by the repetition of compressed anticlines and synclines. I have already mentioned that in Hazara district, the Kiotos rest upon the Attock slate with discordance in the south-east, *i.e.*, that part which is continuous with the strike of the Kala Chitta. Again in the Peshawar district, the map accompanying A. B. Wynne's paper on the area [1] shows that the Kioto-Laki limestone suite of rocks abuts on the Attock slate south of Nowshera in the Cherat hills. The Attock slate, therefore, underlies the Kioto limestone without the intervention of the Infra-Trias at either end of the Kala Chitta. It is, therefore, to be presumed that it underlies the Kiotos in the Kala Chitta itself. The fact that it does not outcrop in the anticlinal cores is due to its not having been folded. Owing to the incompetence of the slates, lateral pressure would merely develop innumerable small glide-planes, while the whole mass would gently swell upwards. Lateral pressure would, on the other hand, compress the hard limestones of the Kala Chitta into sharp folds thus yielding the anticlinorium structure. The result is *décollement*.

Sections through the Isoclinal and Fault Belt South of the Kala Chitta.

In the north of the Fatehjang tahsil, to the south of the Kala Chitta, the Chharat anticline stretches from a spot over two miles north of Fatehjang, running westward to its western termination north of Kutchra village, a distance of about ten miles. Sections through this anticline are given in Sir Edwin Pascoe's work.[2] Sir Edwin points out the intensity of the folding; and although the anticline is frequently crushed so that the structure tends to be isoclinal, the crestal structure is preserved in certain sections. This area has been dealt with in such detail already that no further description is needed.

[1] *See* map facing p. 107, *Rec. Geol. Surv. Ind.*, X, (1877).
[2] *Mem. Geol. Surv. Ind.*, XL, Pt. 3, Pl. 72, (1920).

Plate 15, fig. 11, shows a section by Mr. Lahiri through the Khair-i-Murat range. This section is drawn in a north-south direction through the village of Phamra Khalsa, which is $4\frac{1}{2}$ miles east of the main road from Fatehjang to Khaur oilfield, and is one mile south of the Khair-i-Murat range. The section shows vertical, isoclinal structure in the south and overturned dips to the north, the Laki limestone being brought over the Kamlials and again over the Chinjis by two reversed faults (thrust-faults of steep angle).

These two reversed faults coalesce in the neighbourhood of Gallil Jagir on the Fatehjang-Khaur road. Westward, the reversed fault, now a single one, can be traced west of Dhok Maiki and south of Dulhal, where the ridge of Laki limestone dies out. The fault can be traced westwards, although obscured by alluvium, to Nathial. Westwards, it is again seen one mile W. S. W. of Chhajimar village, and has been traced from there past Thatti Sahidan to a spot 5° N. of E. and five miles distant from Jand, where it dies out. This fault, which may be termed the Khair-i-Murat fault, commencing at Murat, near the border of Rawalpindi district, extends for nearly fifty miles, first on the southern margin of the Khair-i-Murat, and then through the Tertiary freshwater deposits of the Pindi Gheb tahsil.

Khair-i-Murat faults.

Plate 15, fig. 12, shows a section drawn N.-S. from a point three-quarters of a mile south of Dulhal village, through Sadrial village to a point half a mile east of Bora village. It thus shows the country south of the Khair-i-Murat, and the eastern termination of the Khaur anticline. Its northern part is in the *fault* belt; its southern in the *anticlinal* belt, or more correctly the belt of uncrushed anticlines. The northern part of the section shows a crushed anticline of Murree rocks with Kamlials on both flanks. This anticlinal crest although crushed, does not show displacement in the present section. Westwards, however, it becomes strongly faulted, and passes through Mianwala and Jand, and dies out about half way between Jand and Khushhalgarh about three-quarters of a mile south of the Kohat road. It is mentioned by E. S. Pinfold, who erroneously calls it the Mianwali fault [1]; the village from which the name comes is Mianwala, and should not be confused with the name of the town and district headquarters of Mianwali. The

Mianwala fault.

[1] *Rec. Geol. Surv. Ind.*, XLIX, p. 140, (1918).

fault may be known as the Mianwala fault. Pinfold is also wrong in supposing that it crosses the Indus.

South of this crushed anticline, there is a syncline of Chinjis. It will be noticed in this and other sections of the 'fault belt' that while the anticlines are crushed, the synclines remain gentle and unfaulted. South of this again near Sadrial, we observe another crushed anticline, but this time showing fold-faulting and displacement, so that the Kamlials on the south are brought into juxtaposition with the Murrees on the north. This third fault has been traced westwards, past Bakhuwala and Thatti Kaira to Kanet village; from Kanet it runs W.N.W. to a point about $1\frac{1}{2}$ miles south of Jand, and then passes under alluvium to a spot north of Loharandi Dhok, where it can be again traced westwards. Curving round to a direction south of west, it passes south of Bela village, and so across the Indus.

Kanet fault.

These three great fold-faults, the Khair-i-Murat, the Mianwala, and the Kanet fault (as the last may be called) constitute the main faults of the 'fault belt'. In the country south and south-west of Jand, there are two other fold-faults south of the three above described. An examination of the map will show that all these faults are disposed in *echelon* formation, the more southerly reaching farther to the west.

The southern quarter of the section shown in Plate 15, fig. 12, shows the Khaur anticline. The structure is simple, but the north flank of the anticline is faulted by two strike-faults. This southerly region is the belt of uncrushed anticlines, and immediately south of this is the very gentle, very broad, Soan geosyncline.

Plate 16, fig. 13, shows a section by Mr. Lahiri from Dhok Daryan village to Khaur oilfield. This section runs in a direction 15° E. of S. from the village, and passes through the central portion of the Khaur oilfield. The three faults shown in the northern portion of the section are respectively the Khair-i-Murat fault, the Mianwala fault, and the Kanet fault. The syncline between the Khaur anticline and the Kanet fold-fault is simple and unfaulted.

Kharpa fault.

Plate 16, fig. 14, shows a section from Thatti Sahidan village to Kharpa village. In the north is the Khair-i-Murat fault, with a minor imbrication fault to the north of it. Further south, the Mianwala and Kanet fold-faults are seen, while near Kharpa the Kharpa anticline is fold-faulted. This Kharpa fold-fault becomes an important dislocation

when traced westwards and, passing south of Kore Dhok, it crosses the railway south of Uchhri, and so goes west past Dupur and across the Indus.

In the country east of Jand, a section from Chura through Gulial Bhal village is shown in Plate 16, fig. 15. Here, the Khair-i-Murat fault is seen, and it dies out a very short distance west of this line. But the Mianwala fault is still a strong dislocation, and so too is the Kanet fault to the south. The three faults are now close together, the Kanet fault being only 4½ miles distant from the Khair-i-Murat fault. The syncline of Chinji rocks at Gulial Bhal is simple and unfaulted.

Jhamat fault.

Plate 17, fig. 16, shows a section from the Indus river from a point about 1¼ miles north-west of Ratti Kheri village southwards to Makhad Road railway station. In the north this section shows two fold-faults, with an unfaulted syncline between them. The more northerly of the two faults is the Kharpa fault which passes Uchhri and Dupur, and which appeared in section Plate 16, fig. 15. The southerly fault may be called the Jhamat fault.[1] It starts close to Jhamat village which is close to the railway and about half way between Uchhri and Chhab stations. Eastward, it is continued as a sharp anticlinal fold without dislocation. Westwards, there is strong displacement, Chinji rocks on the north abutting on Nagris to the south of the line of fault. This fault runs westwards past Matangi village and so across the Indus north of Sharki village.

South of this fault, the structure quickly changes, and the Soan geosyncline is reached. This is a country of very gentle dips, with a terrace structure near Makhad. It will be observed in this section that the 'fault belt' at once passes into the Soan geosyncline belt without any intervening region of unbroken anticlines.

It will be seen from the foregoing section that the 'fault belt' may be defined as a tract of country south of the Kala Chitta, in which the anticlines are fold-faulted by five great faults disposed *en echelon*; namely, the Khair-i-Murat, the Mianwala, the Kanet, the Kharpa, and the Jhamat faults.

[1] E. S. Pinfold [*Rec. Geol. Surv. Ind.*, XLIX, p. 141, (1918)]. calls this fault the Chhab fault, but the fault is three miles north of Chhab, but only half a mile south of Jhamat village. I therefore prefer the name Jhamat fault.

Sections through the Anticlinal Belt.

The so-called anticlinal belt, as far as the Attock district is concerned, merely means the Khaur-Dhulian anticlinal fold, including the Khaur oilfield. Pinfold speaks of a zone of pronounced but open folding of which the dominant structure is the dome in the country south of the Chhab (or Jhamat) fault. This statement requires to be modified. There are no domes between the Jhamat (Chhab) fault and the Soan geosyncline. The Khaur-Dhulian anticline lies some $5\frac{1}{2}$ miles south of the Kanet fault, the Kharpa and Jhamat faults lie entirely to the westward of this anticline. The word 'dome' is hardly applicable to the Khaur-Dhulian fold, which shows an outcrop of Chinji rocks $23\frac{1}{2}$ miles long by $3\frac{1}{2}$ miles wide. The anticline is therefore over six times as long as it is wide, and should perhaps be spoken of as a brachy-anticline.[1]

The anticlinal belt then, hardly deserves the important position as a definite belt of domes, which has been assigned to it by Pinfold, and in point of fact, it is reduced to a single anticline. It may, however, be pointed out that, viewed in detail, the Khaur-Dhulian anticline can be regarded as three separate brachy-anticlines in one. The Khaur brachy-anticline is a separate structure from the Dhulian brachy-anticline, although the Chinji outcrop links them both together into a single anticlinal area surrounded by Nagri rocks. If the line of the Dhulian crest were produced eastwards it would run about three miles south of and parallel to the Khaur crest. The Dhulian brachy-anticline lies entirely to the west of that of Khaur and succeeds to the Khaur anticline by *echelon* structure. West of Dhulian there is again a change of the crest by *echelon* structure, so that the new crest, west of the road from Pindi Gheb to Talagang, is on a strike some three furlongs north of the strike of the Dhulian crest.

A section through the Khaur anticline has been already given in Plate 15, fig. 12. Other sections through this and the Dhulian fold are given on Plate 78 of Sir Edwin Pascoe's memoir.[2] Plate 17, fig. 17, also shows a section through Dhulian village and the anticline. The anticline dips more steeply on the southern than on the northern flank.

[1] *See* E. Haug, 'Traité de Géologie', Fasc. I, p. 204, (1911).

[2] *Mem. Geol. Surv. Ind.*, XL, Pt. 3, (1920).

Sections through the Soan Geosyncline.

A section from the Khaur oilfield at Lat. 33° 15′ : Long. 72° 30, drawn in a direction 8° E. of S., to the ruins of Samarkand Fort south-east of Maira village a few miles north of the Salt Range, is shown in Plate 17, fig 18. The Soan geosyncline is shown as a very flat broad syncline, about 30 miles across from the Chinji rocks of Khaur to the Chinjis of the northern flank of the Salt Range. This 30 mile stretch is occupied by Middle Siwalik rocks (Nagri and Dhok Pathan stages). It will be seen that the geosyncline flattens out into a terrace to the south. The same feature is to be noticed in the section shown in Plate 17, fig. 16. A third section from a point on the Soan river $5\frac{1}{2}$ miles west of Dhok Pathan village to Chinji is given by G. E. Pilgrim.[1] In this section, in the southern portion of the Soan geosyncline, a gentle anticlinal fold is shown south of Kufri village, which lies seven miles west of Talagang. I examined the country round Kufri, but could not confirm the presence of this anticline. The dips are horizontal at Kufri, and in the area between Dhok Raza and Kufri there are gentle northerly dips.

At the drilled well $2\frac{1}{2}$ miles W. N. W. of Jhatla, the Laki limestone was struck at a depth of 5,925 feet from the surface. It crops out south of Chinji at a distance about 14·7 miles from this well. The general dip of the Laki limestone between the two points is, therefore, nearly 5° northerly. This calculation shows the gentle slope northwards of the southern limb of the Soan geosyncline.

[1] *Rec. Geol. Surv. Ind.*, XLIII, Pl. 28, fig. 2, (1913).

CHAPTER VII.

PALAEOGEOGRAPHICAL THEORIES AND PROBABLE ORIGIN OF THE SALT MARL.

Differences between Salt Range and Kala Chitta sections.

The description of formations given in the foregoing chapters will help us to a more exact comparison between the sections of the Salt Range and those of the Kala Chitta, and other parts of Attock district and of Hazara. It is clear that the difference in the two areas is surprising, in view of their proximity; and it may be said that while there is correspondence from the base of the Cretaceous upwards, there are many points of dissimilarity between the pre-Cretaceous formations of the Salt Range and those of the Kala Chitta. This is perhaps due to the proximity of the Salt Range to the ancient margin of Gondwanaland; this proximity is indicated by the boulders in the glacial boulder bed of the Range, which appear without doubt to be derived from Rajputana [1]; by the resemblance of the fauna of the Speckled Sandstone to the *Eurydesma* horizon of Australia and South-West Africa [2]; and by the appearance of *Gangamopteris* in the Lower Productus Limestone of the Salt Range.[3]

The authority of R. D. Oldham [4] has, in the following sentence, given effect to a far too sweeping view of the change from the Speckled Sandstone with its Australian faunistic affinities to the Productus Limestone fauna above with its erroneously supposed closer relationship with European faunas. He says :—

> 'The change is complete, and with it disappears all connection with the Australian carboniferous fauna, to be replaced by a relationship with the upper carboniferous and permian faunas of Europe.'

[1] *Rec. Geol. Surv. Ind.*, XXV, p. 34, (1892); XLIII, p. 233, (1913); LX, p. 115, (1927); LXII, p. 418, (1930); *Mem. Geol. Surv. Ind.*, XXXV, p. 87, (1902).

[2] 'Manual of Geology of India', 2nd. edn., p. 121, (1893); *Pal. Ind.*, Ser. XIII, Vol. IV, pp. 60, 145, 147, (1889-1892); *Rec. Geol. Surv. Ind.*, XIX, p. 141, (1886); *see also* A. L. Du Toit, 'A Geological Comparison of South America with South Africa', Pub. 381, *Carnegie Inst. of Wash.*, p. 104, (1927) and T. W. E. David and C. A. Sussmilch, 'Upper Palæozoic Glaciations of Australia', *Bull. Geol. Soc. Amer.*, Vol. 42, pp. 481-522, (1931).

[3] *Rec. Geol. Surv. Ind.*, LXII, pp. 422, 443, (1930).

[4] 'Manual of Geology of India', 2nd edn., p. 124, (1893).

Productus Limestone fauna not foreign to Gondwanaland.

It must, however, be noted that in the list of species from the post-glacial beds of the Argentine given in F. R. C. Reed's appendix to A. L. Du Toit's paper (*loc. cit.*, p. 146) above quoted, there are a few Indian species, and the want of closer correspondence is perhaps due to a difference in age, while, in Western Australia, A. Gibbs Maitland (*see* David and Sussmilch, *op cit.*, p. 515) [1] has shown that there is a very close relationship between the fauna of the Permian of that country with the fauna of the Salt Range Permian. Our notions of the sudden change in provincial relationships of the fauna with the incoming of the Permian (Productus Limestone) period must, therefore, be seriously modified.

Permian marine transgression.

Nothing more startling seems to have occurred than a marine transgression in the Salt Range, bringing with it a more cosmopolitan fauna with some European affinities, by the invasion of the waters of the sea which separated Gondwanaland from the northern continents ; but there is no trace of any land barrier or faunistic separation from the Permian fauna of Gondwanaland.

The Productus Limestone has a limited extension in the Salt Range. According to A. B. Wynne [2] its most easterly occurrence is in the Nila Wahan (Wynne's Nilawan ; 32° 37′ : 72° 37′) glen. From there it extends throughout the western Salt Range to Daoud Khel, and is found throughout the Trans-Indus extension of the Salt Range.[3] There is no trace of the Productus Limestone between the Kioto limestone and the Attock slate in north Attock, in Peshawar, and in south-east Hazara ; in north-west Hazara the Infra-Trias probably is homotaxial with the Productus Limestone.[4] In Afghanistan between Jalalabad and Kabul, the Khingil series are in part equivalent to the Productus Limestone ; so too is the Fusulina Limestone west of Kabul,[5] but these are probably not Gondwanaland deposits. The Zewan beds of Kashmir and the Productus Shales of the Spiti-Kumaon area are to be correlated also with the upper half of the Productus Limestone of

[1] *See also* A. Gibbs Maitland, 'Summary of the Geology of Western Australia', (1924).

[2] 'Geology of the Salt Range,' *Mem. Geol. Surv. Ind.*, XIV, p. 93, (1878).

[3] *Mem. Geol. Surv. Ind.*, XVII, Pt. 2, p. 29, (1880).

[4] *Mem. Geol. Surv. Ind.*, IX, p. 335, (1872) ; XXVI, p. 17, (1896) ; *Rec. Geol. Surv. Ind.*, LXII, p. 152, (1929) ; LXIII, p. 130, (1930).

[5] *Mem. Geol. Surv. Ind.*, XXXIX, pp. 21, 26, (1911).

the Salt Range and appear to belong to the same faunistic province.

The absence of the Productus Limestone in the eastern Salt Range might conceivably be due to its removal through denudation in Lower Eocene or earlier times. An examination of the sections in the plate facing page 42 of *Rec. Geol. Surv. Ind.*, XXIV, will show that the Productus Limestone is absent as part of the huge stratigraphical gap that exists between the Ferruginous Pisolite (basal Laki) and the Speckled Sandstone (Upper Carboniferous). But its absence from Peshawar and south-east Hazara where the Kiotos directly overlie the Attock slates, cannot be interpreted in this manner. It has either been removed by some pre-Kioto denudation, or, since there is discordance between the Kiotos and the Attock slates, it seems more probable that it was never deposited in these areas. The view that the Productus Limestone was never deposited in north Attock, etc., is perhaps strengthened by the occurrence of a freshwater horizon with plant-remains (*Gangamopteris*, etc.) in Kashmir immediately below the Zewans. Whatever be the cause of the absence of the Productus Limestone in north Attock, it is clear that it was absent at the commencement of Kioto times.

Limited extent of Productus and Ceratite Limestones.

Cambrian rocks: limited extent.

Another suite of rocks of very limited extension in the Salt Range is the Cambrian suite, that is in descending order.—

(3) The Salt Pseudomorph zone.
(2) The Magnesian Sandstones.
(1) The Neobolus beds.

and to these may be added the pre-Cambrian formation underlying these rocks, *viz.*

The Purple Sandstone.

The Purple Sandstone extends throughout the Cis-Indus Salt Range, but it is invisible in the Trans-Indus extension of the Range. It is absent everywhere in north Attock, Hazara and Peshawar above the Attock slate, and it may be conjectured that it is a local shore deposit of Gondwanaland, not extending to Attock and Hazara.

The Cambrian suite of rocks is much more limited in extension. These rocks are found only in the eastern Salt Range, and are not seen west of Katha (32° 31′ 30″ : 72° 25′). The Talchir boulder bed oversteps the Salt Pseudomorph zone west of Makrach glen

(32° 40′ : 72° 53′ 30″), and the rest of the Cambrian suite in succession, until west of Katha it rests directly upon the Purple Sandstone. There is, therefore, unconformity between the Talchir boulder bed and the rocks below, which presumably have been denuded away. There is, however, no visible dip discordance.

Palæozoic stratigraphical gap.

There is one great point of similarity between Hazara pre-Talchir sections and those of the Salt Range, in that the greater part or even, in some sections, the whole of the Palæozoic rocks are generally missing. The Cambrian of the Salt Range is of local distribution, and the capping Salt Pseudomorph zone, with its bright red clays, is exactly the type of formation that one associates with marine regression and the oncoming of shore conditions. It may, therefore, be assumed that the Salt Range, the Attock district and Hazara were land in Palæozoic times, forming part of Gondwanaland. In the Pamirs, there are Devonian marine deposits, and Silurian to Devonian in Kashmir [1]; a Palæozoic sea lay, therefore, to the north-east and north-west of Hazara and Attock.

Permian oscillations.

It appears that in Permian times a period of compensatory oscillations commenced, so that while marine transgression is found in the Salt Range, there is a continuance of land conditions in north Attock and south-east Hazara, and again marine transgression in north-west Hazara. This transgression laid down the Productus Limestone of the Salt Range and the Infra-Trias of Hazara. It may here be noted that we do not know the exact age of the so-called Infra-Trias; all that can be said is that it is infra-Kioto or pre-Noric and post-Talchir or post-Upper Carboniferous.

Lower Trias.

The marine transgression continued into the Lower Trias to which the Ceratite Limestone of the Salt Range must be referred. There is no trace of the Lower Trias in north Attock nor in Hazara district. In western Kashmir and Poonch this system (known to Indian geologists as the Lilang system) appears to be poorly developed or wanting,[2]

[1] There are Devonian deposits in Chitral and Afghanistan also [see *Pal. Ind.*, N. S., Vol. VI, Mem. No. 2, pp. 130-131, (1922), and *Rec. Geol. Surv. Ind.*, XLI, p. 103, (1912)], but these differ faunistically from the Pamir fauna and are more probably deposits associated with the northern continents, rather than with Gondwanaland. The fauna of the Pamirs is, however, probably a Gondwanaland fauna.

[2] *Mem. Geol. Surv. Ind.*, LI, p. 250, (1928).

but it is developed in the Vihi district and the Lidar valley of Kashmir,[1] and further east it is found in Spiti and Kumaon.[2]

It may be assumed, therefore, that the marine transgression which laid down the Productus and Ceratite Limestones of the Salt Range did not affect north Attock and south-east Hazara, which were probably land.

Upper Trias and Lias: Kioto limestone.

In the Upper Trias and the Lias, we find a marine transgression affecting the north Attock and Hazara areas. The Kioto limestone is a very widely spread formation extending from Kumaon through Spiti to Kashmir, Hazara, Attock, and Peshawar. But in the Salt Range this limestone is not to be found.

Mesozoic deposits of Salt Range imperfectly known.

It must be said that the geology of the Salt Range Mesozoic rocks is still imperfectly known. Some corrections have to be applied to A. B. Wynne's early description. The work of F. Noetling and of E. Koken is fragmentary, while E. R. Gee has not yet mapped the area round Sakesar, where Mesozoic rocks occur. Over the greater part of the Salt Range there is a hiatus between the Ceratite Limestone or the Speckled Sandstone and the Tertiary.

Belemnite beds as datum line.

It has been noted in a preceding chapter that the Valanginian occurs in the Salt Range near Sakesar. The Lower Cretaceous belemnite beds are a well marked horizon in the Trans-Indus Salt Range.[3] Beneath these beds, the nearest approach to the Kioto limestone is a band of dolomite above the Ceratite Linestone, which Wynne describes as being 150 to 250 feet thick in the Kingriali cliffs of the Khasor hills,[4] and 200 to 300 feet thick in the Sheikh Budin hills,[5] but it is to be noticed that in the Kalabagh section[6] the dolomite is absent.

Dolomite band may be equivalent of Kiotos.

Giumal–Spiti shale horizon.

Again, in the section near Sakesar given by E. Koken[7] there is a thin bed, six metres thick, of dolomite shown above the Trias and below the Giumal–Spiti shale sandstone group, but it is not certain whether this corresponds

[1] *Rec. Geol. Surv. Ind.*, XL, p. 241. (1910); XLIV, p. 39, (1914).
[2] *Mem. Geol. Surv. Ind.*, V, p. 30, (1865); XXXVI, Pt. 3, (1912).
[3] *Mem. Geol. Surv. Ind.*, XVII, Pt. 2, pp. 26, 40, 47, 78, (1880).
[4] *Mem. Geol. Surv. Ind.*, XVII, Pt. 2, p. 70, (1880).
[5] *Ibid.*, p. 76, (1880).
[6] *Ibid.*, p. 40.
[7] *Centralbl. f. Min. Geol. und Pal.*, p. 441, Fig. 1, (1903).

to the Kioto limestone or not. In any case, it may be concluded that the Kioto limestone is absent generally in the Salt Range. We might suppose that the marine transgression of the Kioto limestone in north Attock and Hazara is compensated by a regression in the Salt Range.

Terebratula bed of Nila Wahan.

The Giumal–Spiti shale horizon of the Salt Range is in great need of further study. E. R. Gee[1] notes the occurrence at Nila Wahan of a bed of *Terebratulae* and echinoids underlying marls and sandstones with nummulites. These last are clearly the Laki variegated sandstones described in a previous chapter. But the *Terebratula* bed looks very like a bed described by Koken,[2] and containing *Waldheimia* and a reptilian femur probably *Belodon* or *Massospondylus*.

Koken refers this bed to the Upper Trias or Lias; if this is correct, it indicates shallow water deposits in Kioto times in this area. But Gee states that the *Terebratula* bed is underlain by a bed of pisolitic hematite. This pisolite must be much older than that at the base of the Laki, even if the *Terebratula* horizon is later than Upper Trias to Lias. This question may be left aside for the present. It may be noted that *Terebratula* beds occur both above and below the Belemnite beds in the trans-Indus extension of the Salt Range.[3] It is possible that the ferruginous pisolite underlying the *Terebratula* bed may be a Callovian pisolite like the '*Sulcacutus*' bed of the Himalaya. I have noted, in a preceding chapter, that there is, according to Mr. Lahiri, a laterite horizon at the top of the Kiotos, corresponding to the '*Sulcacutus*' horizon.

At any rate, it is clear that the Kioto limestone is generally missing throughout the Salt Range, and as far north as Kalabagh. Somewhere south of the Kala Chitta this limestone thins out, and the Laki limestone and perhaps the Spiti shale–Giumal rocks rest directly on the Attock slate. But the Spiti shale–Giumal group is also poorly represented in the Salt Range, although its thickness appears to be considerable in the trans-Indus extension of the Range.

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 161, (1929).

[2] *Op. cit.*, pp. 440, 441.

[3] *See Mem. Geol. Surv. Ind.*, XVII, Pt. 2, p. 81, (1880), where in the Khavuri *tanga*, *Terebratula* occurs above the Belemnite horizon, and also page 77 for the occurrence of *Terebratula* below.

Section in trans-Indus extension of Salt Range.

A. B. Wynne[1] makes out the following succession in the Trans-Indus Salt Range between the base of the Tertiary and the Ceratite Limestone :—

8. Whitish sandstones over dark earthy zone containing a few Neocomian fossils.

(*Partial unconformity at one place.*)

7*b*. Light coloured, thin limestones and shales with a dark earthy zone on top; containing *Ammonites*, *Belemnites*, etc.

7*a*. Variegated, soft sandstones and clays often coaly, or alum shale. Fossils chiefly obscure plants; limestones subordinate.

Wynne attributes bed 8 to the Cretaceous and beds 7*a* and 7*b* to the Jurassic. The fossil plants have not been identified, but some impressions resemble the pinnules of *Ptilophyllum*.

Unfortunately, in the absence of accurate determinations of the apparently rich fauna, it is impossible to be certain of the correlation of these interesting beds. But as a working hypothesis, we may perhaps suppose that the horizon 7*b* corresponds to the *Olcostephanus* beds of Thal[2] which are of lowermost Hauterivian age, according to Spath. If that be the case, we may further correlate the white sandstone of bed 8 with the similar white sandstone which succeeds the *Olcostephanus* beds of Thal, and also with the white sandstone which overlies the beds with '*Hoplites neocomiensis*' of Sakesar in the Salt Range. In that case, beds 7*b* and 8 are both Neocomian and below the Gault. In the Samana range, these sandstones are capped by a layer rich in Gault fossils.

The lowest layer with fossil plants is probably Upper Jurassic, although there is not much evidence as to their age. But the fossil-plant horizon overlies the dolomite in the Kingriali cliff section (*see* above), and if the dolomite corresponds, as has been suggested, to the Kioto limestone, then the plant beds will belong to some part of the Upper Jurassic either of Callovian or post-Callovian age, and will correspond with the pre-Neocomian portion of the Spiti shale group.

Fossil plant bed as datum-line.

[1] *Mem. Geol. Surv. Ind.*, XVII, Pt. 2, p. 26, (1880).

[2] *See* remarks of L. F. Spath on the correlation of the Thal beds with those of the Salt Range :—*Pal. Ind.*, N. S., Vol. XV, Pt. V, p. 59, (1930).

E. R. Gee[1] describes similar plant beds at the same horizon on the slopes of Sakesar Hill. Here the Ceratite beds are followed by a series of massive, white, yellow and reddish sandstones with some blue grey and light coloured clays. To the north of Sakesar, Gee found in these beds well-preserved plant impressions of Mesozoic age.

Correlation table.

This horizon is clearly the same as the bed marked 7*a* in the succession quoted from Wynne's account of the Trans-Indus Salt Range. By combining Gee's notes on the geology round Sakesar with Koken's work, it would seem that the whole succession, described by Wynne, is represented in the Sakesar area, that is as follows[2] :—

Horizon.	Sakesar area.	Trans-Indus Salt Range.	Thal.	North Attock, Kala Chitta area.
Albian . .	White sandstone	White sandstone	Main sandstone series.	Giumal shell limestone capped by *Oxytropidoceras* beds.
Lowermost Cretaceous.	Beds with *Hoplites neocomiensis*.	Thin limestone with ammonites and belemnites.	Belemnite bed with *Olcostephanus*.	Shell limestone with *Trigonia ventricosa*, *T. smeei*.
Upper Jurassic .	Sandstones with plants.	Sandstones with plants.	Samana Suk limestone and lowest Samana beds.	Beds with *Spiticeras*, *Himalayites*. Beds with *Mayaites maya*, *Peltoceratoides*, etc.

If the above correlation table is correct, it appears that: (1) the Kioto limestone is absent in the Salt Range; (2) the Spiti shale horizon of Attock is represented by plant- and coal-bearing beds in the Salt Range; (3) that the Gault is not represented by a recognisable fossiliferous horizon; (4) that there is a fair correspondence between what is left of the Upper Jurassic and Cretaceous of the Salt Range and the corresponding rocks of Attock district.

I have above discussed the occurrence of *Terebratula* in the Nila Wahan section described by E. R. Gee. It is possible also that the *Terebratula* horizon will turn out to correspond with the Albian, *i.e.*, the beds above the Belemnite beds, and not with the lower

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 163, (1929).

[2] *See* E. Koken, *op. cit.*; A. B. Wynne, *Mem. Geol. Surv. Ind.*, XVII, Pt. 2, (1880); E. R. Gee, *Rec. Geol. Surv. Ind.*, LXII, p. 163, (1929) (as quoted in Director's Annual Report); L. M. Davies, *Pal. Ind.*, N. S., Vol. XV, Pt. I, p. 5, (1930); L. F. Spath, *ibid.*, Pt. V, p. 49, (1930).

Terebratula horizon of the Trans-Indus Salt Range. If so, it would probably be of Gault age, and would then correspond with the Gault of Samana which is rich in *Terebratula*. In the Nila Wahan section, all the rocks between the Productus Limestone and the Gault would then be missing, with the exception of the pisolitic hematite, which seems to point to an old shore deposit, probably of basal Cretaceous or Jurassic age.

Jurassic, a time of land conditions.

It would appear from the foregoing that there is evidence of land conditions in the Salt Range in Jurassic times, perhaps throughout Jurasic times, but that a Lower Cretaceous marine transgression brought marine deposits as far east as Sakesar, and perhaps Nila Wahan glen.

Stratigraphical gap above the Gault.

Above the Gault, there is all over North-West India, Baluchistan and Sind, a very widespread stratigraphical gap, whereby the middle and part of the Upper Cretaceous from the Cenomanian to the Santonian are missing. With the Campanian, the first signs of marine transgression are indicated by the *Hemipneustes* beds of Sarawan in Baluchistan. The Maestrichtian to Danian is a period of advancing marine transgression, and the Pab sandstones of Baluchistan, the *Cardita beaumonti* beds of Sind and Baluchistan, and similar beds in the Sulaiman range belong to these stages. In the Samana range, L. M. Davies[1] refers some beds termed the Lower Lithographic Limestone, the Variegated Bed, and the Upper Lithographic Limestone to the Cretaceous above the unconformity at the top of the Gault, and it would appear that the Upper Cretaceous marine transgression reached Kohat district. There is, however, no trace of these beds either in the Salt Range proper, as far as Mr. E. R. Gee's re-examination of it has gone, nor have other observers found either in the Salt Range itself, nor in its Trans-Indus extension, any trace of such beds, nor, according to my own and to Mr. Lahiri's observations, are such beds present in north Attock. In the northern part of that part of Hazara district mapped by C. S. Middlemiss, there is a grey limestone, which may be Upper Cretaceous, but Middlemiss states that it appears to be absent in the southern part of the district.[2] In

[1] *Pal. Ind.*, N. S., Vol. XV, Pt. 1, p. 9, (1930).

[2] *Mem. Geol. Surv. Ind.*, XXVI, p. 39, (1896).

three areas—the Salt Range, the trans-Indus extension, and the Kala Chitta of northern Attock—the pisolitic hematite at the base of the Laki rests directly upon the Giumal–Spiti shale unit or on older beds, and the whole of the Middle and Upper Cretaceous and the Ranikot stage [1] of the Eocene are missing, as far as we know at present, although it must of course be remembered that the present re-examination of the Range by Mr. E. R. Gee is not yet completed, and the trans-Indus extension has not been resurveyed since Wynne's first map of 1879. But Ranikot deposits are developed at Thal and Hangu in the Kohat district. The Ranikot stage is absent from Baluchistan, and is overlapped by the basal Laki in Sind,[2] showing that oscillatory movements took place at the close of Ranikot times.

Limited extent of Ranikot deposits.

Both the commencement and the close of the Ranikot appear to be marked by marine retreat in Sind. E. Vredenburg [3] says:—

Ranikot a period of limited and temporary oscillations.

'Even in Sind sedimentation was not continuous, for the basalt overlying the *Cardita beaumonti* beds has all the appearance of a sub-aerial flow, indicating an interval of continental conditions.'

He proceeds to show that in the Lower Ranikot, there was a temporary return of the sea, followed again by freshwater deposits, this being followed by a new marine transgression to bring in the Upper Ranikot beds. But this transgression was of short duration, since the basal Laki commences with a laterite bed overlying unconformably the Ranikot beds. Hence the Ranikot was an age of temporary and localised advance of the sea, followed by temporary retreats, and finally by a retreat, which appears, from the widespread occurrence of the basal Laki ferruginous pisolite, to be of a general and more widespread character than the preceding oscillations.[4]

The oscillations which affected Sind and Kohat, and enabled the Upper Cretaceous and Ranikot formations to be laid down, do not appear to have affected the Salt Range, where the basal Laki ferruginous pisolite everywhere rests upon Lower Cretaceous or older

[1] In 1879, the Ranikot stage was defined anew in its present limitations [see *Rec. Geol. Surv. Ind.*, XI, p. 163, (1878)], the term having in former publications included the *Cardita beaumonti* beds, *e.g.*, *Rec. Geol. Surv. Ind.*, IX, p. 9, (1876).

[2] W. F. L. Nuttall, *Rec. Geol. Surv. Ind.*, LXV, pp. 306-313, (1931).

[3] *Pal. Ind.*, N. S., Vol. X, Mem. No. 4, p. 73, (1928).

[4] See *ante* under *Ferruginous Pisolite*, and W. F. L. Nuttall, *op. cit.*, and *Quart. Journ. Geol. Soc.*, LXXXI, p. 421, (1925).

formations. In the Salt Range and its trans-Indus extension, it has been assumed above that the Danian and Ranikot beds are absent. In so extensive a tract, it is difficult not to suppose that some trace of these deposits would remain if they had been originally deposited. It seems much easier to think that the Salt Range was dry land throughout the Ranikot stage. The temporary and localised character of the marine advance and retreat in Sind, noticed by Vredenburg, the widespread absence of the Ranikot in Baluchistan, and the absence except, in one place,[1] of the Upper Ranikot in the Samana range seem to point to discontinuous deposition of the Ranikot over localised areas, rather than that it should have once been a widespread deposit which has afterwards been extensively denuded.

Probable Ranikot lagoon in Potwar.

We may suppose then that an arm of the Ranikot sea extended to Thal and Hangu in the Kohat district, but as far as our present knowledge goes, did not reach the Salt Range, nor the Kala Chitta. It may, however, have extended to the Kawa Gar area north of the Kala Chitta, for, as we have seen, there are some shales below the pisolite, which were doubtfully referred to the Ranikot. Further, it seems probable that underneath the Potwar, Ranikot deposits underlie or underlay the Laki limestone, although they are absent from the Salt Range. If, as seems likely, the Salt Range was above water in Ranikot times, it is probable that it merely formed a barrier to an inland sea covering the Potwar. As an indication of this, I shall show that the Potwar has been a subsiding area, from early Tertiary times up to the close of Middle Siwalik times.

Attenuation of Tertiaries in Salt Range, and table.

In the following table, the thicknesses of the different stages or series are given from the Dhok Pathan stage downwards :—

Name of formation.	Thickness in Salt Range.	Thickness in north Attock, Rawalpindi, etc.
Dhok Pathan stage . .	2,000—2,100 ft. . .	Greater than 2,000 ft. near Makhad ; top not seen.
Nagri stage . . .	2,460 ft. near Bhaun .	5,300 ft. south of Pindi Gheb.

[1] L. M. Davies, *op. cit.*, p. 12.

Name of formation.	Thickness in Salt Range.	Thickness in north Attock, Rawalpindi, etc.
Chinji stage . . .	1,400-2,600 ft. in Salt Range; 2,800 ft. at Jhatla.	4,000 ft. at Khaur. 4,500 ft. at Mianwala.
Murree series; including Kamlials.	1,400-2,070 ft. (mainly Kamlial).	7,500-8,000 ft. (Wynne) in Potwar. 8,000 ft. in Potwar (Pilgrim). 5,000-8,000 ft. (Anderson).
Chharat series . . .	Absent; or 10-20 ft. .	450-900 ft. in Kala Chitta (Pinfold). 750-900 ft. in Kohat (Davies).
Laki or Hill Limestone .	500-700 ft. . .	1,650 ft. in Kala Chitta.
Ferruginous Pisolite .	Up to 6 ft. . . .	Up to 6 ft.
Giumal-Spiti shale unit . ..	Absent east of Nila Wahan. 280 ft. at Sakesar, (Koken); 500-700 ft. in Trans-Indus Salt Range (Wynne).	300-320 ft. in Kala Chitta. 200-310 ft. in Hazara. About 2000 ft. in Samana range.
Kioto limestone . .	Absent; ? dolomite 6 metres in Sakesar. 300 ft. dolomite in trans-Indus extension of Salt Range.	800-1,600 ft. in Kala Chitta; 500-1,200 ft. in Hazara.

From the table given above, it will be observed that the thickness of every formation from the Kioto limestone upwards is greater in the Potwar and Kala Chitta area than in the Salt Range. This feature is especially noticeable from the Laki limestone to the Nagri stage. It may be concluded that the attenuation of the deposits in the Salt Range area is due to the proximity of a shore line to the south, or a geoanticlinal axis. The Potwar, on the other hand, must have been a constantly subsiding geosyncline since early Tertiary times. That the Salt Range was being actively denuded at the close of the Dhok Pathan stage is shown by the presence of boulders in the basal Upper Siwalik conglomerate (*see ante*), which are derived from the Talchir boulder bed. But in earlier times, it must have been dry land, or there must have been land to the south, otherwise it seems hard to account for the regular subsidence along the axis of the Soan geosyncline, and the attenuation of

strata on the southern flank, which point to the proximity of the geoanticline which rose as the geosyncline sank.

We therefore arrive at the idea of an inland sea in the Potwar in early Tertiary times, bounded on the south by the rising geo-anticline which eventually formed the Salt Range. To the north, it was bounded by the Kala Chitta during late Ranikot or early Laki times, since the ferruginous pisolite at the base of the Laki extends to the Kala Chitta and to Hazara. The extensive marine transgression which laid down the Laki limestone over both the Salt Range and the North Attock-Hazara area, must have been preceded, as in Sind, by a stage of temporary advances and retreats of the sea, and of warpings of the strata. It seems then quite reasonable to suppose that the first warpings, which eventually grew into mountain building movements to form the Kala Chitta and Salt Range, commenced in early Eocene times. The ferruginous pisolite, which is found both in the Kala Chitta and the Salt Range, may well be the attenuated representative of a thick deposit in the geo-synclinal area of the Potwar and Soan valley, just as the Chharats on the south flank of the Kala Chitta attenuate to 20 feet or less on the northern slopes of the Salt Range.

Salt Marl, the probable equivalent of the Ferruginous Pisolite.

If we suppose that the ferruginous pisolite and the unconformity at its base are represented by a fairly thick deposit in the geosyncline of the Soan valley, it may well be that this deposit is the puzzling Salt Marl, which has been extruded all along the base of the Salt Range, but whose original position was beneath the Laki Murree, and Siwalik series in the Soan valley area.

Kohat salt of Ranikot age.

This view, that the Salt Marl is of Ranikot age and has travelled from its original position, has much to support it. In a recent paper[1] Messrs. D. N. Wadia and L. M. Davies argue in favour of the Ranikot age of the salt in the Bahadur Khel section in Kohat. They show that the salt deposit lies immediately below the unconformity at the base of the Laki.

It is not necessary to allude to the work of previous geologists upon the age of the salt. Full references are given in the paper by D. N. Wadia and L. M. Davies quoted above. The question has long been a subject of controversy, and many geologists, including

[1] *Trans. Min. Geol. Inst. Ind.*, XXIV, p. 202, (1929).

Sir Edwin Pascoe, held the view that the Salt Marl was of Tertiary age. But no explanation of the complete absence of the Salt Marl from the Tertiary sections in the upper scarps of the Salt Range has yet been forthcoming. The first distinct advance was made by D. N. Wadia and L. M. Davies in definitely suggesting a Ranikot age for the salt of Kohat.

Supposed Cambrian age of salt.

Those geologists who pointed to the present position of the Salt Marl beneath the Purple Sandstone of the Salt Range as the normal one, were constrained to conclude that the Salt Marl of the Salt Range was an entirely different deposit from the salt of Kohat, and of different age. This view was strengthened by the discovery of Cambrian strata associated with salt deposits in Persia by G. M. Lees.[1] It was argued that if there were salt deposits of Cambrian age in Persia, with rocks suspiciously like the Purple Sandstone above, the salt deposits of the Salt Range might well be Cambrian or even older.

Analogies with Persia.

Gee's discovery of Ranikot fossils in Salt Marl.

But meanwhile, R. van V. Anderson [2] had found specimens of supposed dicotyledonous leaves in the Salt Marl at Khewra. An examination of his locality at Khewra by Mr. E. R. Gee and myself, and a further examination of the actual specimens [3] which were kindly sent to the Geological Survey of India by Mr. Anderson, did not convince either of us of their organic origin, and left open the possibility that they were carbonaceous markings simulating plant-remains.

E. R. Gee's long-continued efforts to find fossils were rewarded, in field-season 1929-30, by the discovery in the Salt Marl near Khewra and Dandot railway station of the following species, which were afterwards identified by Col. L. M. Davies[4]:—

Dictyoconoides conditi
Dictyoconoides haimi
Dictyoconoides newboldi, var.
Nummulites cf. *mamilla.*

These occurred in association with plant fragments, and plant fragments were also found by Mr. Gee in the Salt Marl at the Nila

[1] J. W. Gregory, 'The Structure of Asia', Chapter III (by H de Bœckh, G. M. Lees, and F. D. S. Richardson), (1929).
[2] *Op. cit.*, p. 672.
[3] *Rec. Geol. Surv. Ind.*, LXIII, p. 25, (1930).
[4] *Op. cit.*, LXVI, p. 32, (1932).

Wahan, with crystals of selenite resembling large nummulites or assilines, which he is inclined to consider as crystal growths, possibly round small foraminifera.

Of these foraminifera the first four are of Ranikot age, while *Nummulites mamilla* is a Laki species. Mr. Gee's discovery definitely fixes the age of the Salt Marl as Ranikot (unless we regard the foraminifera as derived, and the beds as later than Ranikot) and agrees with Wadia and Davies' suggestion that the salt of Kohat is of Ranikot age. But the only bed of the Tertiary section which can conceivably be of Ranikot age is the Ferruginous Pisolite. Therefore, the Salt Marl corresponds to the Ferruginous Pisolite, or to the unconformity below the Pisolite.

Its position below the Purple Sandstone is therefore abnormal and due to extrusion, and its normal position would be either immediately below or homotaxial with the Ferruginous Pisolite.

Intrusive character of the salt.

It was pointed out by C. S. Middlemiss [1] that the boundary of the Salt Marl and the Purple Sandstone is brecciated, and this feature of the junction has been further described by F. R. C. Reed, H. M. Lahiri, and myself.[2] The brecciation is evidence that the Salt Marl has moved underneath the Purple Sandstone. Thus the suggestion of C. S. Middlemiss [3] that the Salt Marl is intrusive is somewhat near the present view, but this movement of the salt was not necessarily connected with volcanic activity.[4]

The origin of the Salt Marl, and the question of its intrusive character, or otherwise, has been exhaustively discussed by W. A. K. Christie, who,[5] while not excluding the possibility that its anomalous stratigraphical relationships may be due to ordinary tectonic movements, thinks that its position may be explained as due largely to isostatic adjustment of the salt deposits, which the pressure of superincumbent strata had rendered plastic. Other causes of disturbance of the marl, he suggests, may be changes in volume of the salt and solution.

[1] *Rec. Geol. Surv. Ind.*, XXIV, p. 32, (1891).
[2] *Op. cit.*, LXII, pp. 414, 416, (1930).
[3] *Op. cit.*, XXIV, p. 40, (1891).
[4] It must be recorded, however, that Mr. E. R. Gee, who has read the manuscript of this memoir, and made certain comments thereon, maintains that the views advocated by me regarding the intrusion of the Salt Marl into the Salt Range area are, as a main feature, contrary to field evidence, collected by him through four and a half field-seasons' work, and he holds that the Salt Marl is *in situ*, except for minor phenomena.
[5] *Rec. Geol. Surv. Ind.*, XLIV, pp. 252-264, (1914).

M. Stuart[1] mentions Middlemiss' view of the igneous or *quasi-igneous* origin of the salt, but, while noting its foliated and fluxioned character, is clearly in favour of the view that it is broadly *in situ*. As has been recorded in a footnote, somewhat similar views are held by Mr. E. R. Gee.

I recognise that due weight must be given to the views of such competent observers, but nevertheless I adhere to my view of the intrusive character of the Salt Marl, although I regard this intrusion as not due to volcanic but to tectonic causes. I have not only the authority of C. S. Middlemiss on my side, but also the cumulative evidence of much recent literature upon the mobile character of salt deposits. The intrusion is of course assumed to affect only the Cis-Indus Salt Range, where the position of the Salt Marl beneath the Purple Sandstone is anomalous, and not the Kohat area to which M. Stuart's remarks more especially apply, and where the salt is assumed by me to be in its normal position, as has been held by many others including D. N. Wadia and L. M. Davies, whose paper has been frequently quoted.

Recent work on salt domes.

It is unnecessary to do more than point out that recent work on salt deposits[2] has shown that such deposits show in other areas clear evidence of similar movements to those now postulated for the Salt Marl of the Salt Range.

Ancient rocks underlying Salt Range and Kala Chitta.

Let us now consider such evidence as we possess of the nature of the older rocks underlying the Kala Chitta suite of Mesozoic and Tertiary rocks and the Salt Range suite from the Purple Sandstone upwards. It has been suggested in a preceding chapter that the rocks underlying the Kioto limestone of the Kala Chitta are the Attock slates. In the case of the Salt Range, nothing older than the Purple Sandstone is visible; the Purple Sandstone is underlain by the Salt Marl. In the Kirana hills near Sargodha, and about 43 miles distant from Nila Wahan in the Salt Range in a southerly direction, outcrops of pre-Cambrian rocks protrude from the alluvial plain. These rocks consist mainly of shales and slate with quartzites, and with interstratified igneous rocks, and occasional beds of tuff. These rocks are described by A. M. Heron.[3]

[1] *Rec. Geol. Surv. Ind.*, L, p. 61, (1919).

[2] *See* J. W. Gregory, Structure of Asia, Chapter III, (1929), and *Journ. Inst. Pet. Tech.*, XVII, pp. 251-383, (1931), in which a series of papers, with full references to previous literature, on salt deposits, is given as a symposium on salt domes.

[3] *Rec. Geol. Surv. Ind.*, XLIII, p. 229, (1913).

There are several points of difference between the slates of the Kirana hills and the Attock slates; the latter are free from igneous beds and from quartzites in the Attock hill outcrop. Quartzites, however, occur in the slates of the Hazara foothills north of Burhan, and are mentioned by C. S. Middlemiss from the slates of Hazara.[1] In Poonch and south-west Kashmir, D. N. Wadia [2] found the Dogra slates to be interbedded with contemporaneous lavas. On the whole then, there seems some reason for correlating in a general way the slates of the Kirana hills with the Attock, Hazara, and Dogra slates. At any rate, they all form part of the floor of Gondwanaland upon which later deposits were laid down.

Similarity of Kirana rocks to those of Attock and Kashmir.

It has been shown in a preceding chapter that the structure of the Kala Chitta has been produced by *décollement*, the suite of rocks from the Kioto limestone upwards sliding upon a floor probably of Attock slate, and becoming intensely folded in the process. Similarly, the Salt Range appears to have moved with reference to the floor of older rocks beneath it; the overthrust nature of the structure has been demonstrated by E. R. Gee in the Jalalpur area.[3] It may then be assumed that the sliding plane, over which the Kala Chitta rocks have been compressed and folded, is continued southwards, and that the Salt Range has also moved by a southward thrusting movement over the floor of older rocks composed, perhaps, of Attock and Kirana slates.

***Décollement* of Kala Chitta.**

If the sections of the Salt Range be compared with those of the Kala Chitta, it becomes clear that a deposit of Salt Marl of Ranikot age might, in the Potwar, have touched this floor of older rocks. I give below the two sections side by side:—

Salt Range section compared with that of Kala Chitta.

Horizon.	Salt Range.	Kala Chitta.
Eocene	Laki limestone . Variegated Sandstone . Ferruginous Pisolite .	Laki limestone. Variegated Sandstone. Ferruginous Pisolite.

[1] *Op. cit.*, p. 11.
[2] *Mem. Geol. Surv. Ind.*, LI, p. 228, (1928).
[3] *Rec. Geol. Surv. Ind.*, LXIII, p. 136, (1930).

Horizon.	Salt Range.	Kala Chitta.
	(Assumed horizon of Salt Marl in Potwar.)	
Lower Cretaceous and Upper Jurassic.	Absent, except west of Nila Wahan.	Giumal–Spiti shale unit.
Lias and Upper Trias .	Absent, except 20 feet of dolomite near Sakesar.	Kioto limestone.
Lower Trias . . .	Ceratite Limestone .	Absent.
Permian	Productus Limestone .	Absent.
Upper Carboniferous .	Speckled Sandston and Talchir boulder bed.	Absent.
Cambrian . . .	Salt Pseudomorph zone .	Absent.
	Magnesian Sandstone .	Absent.
	Neobolus beds . .	Absent.
Lower Cambrian or pre-Cambrian.	Purple Sandstone . .	Absent.
Pre-Cambrian . . .	Slates of Kirana hills .	Attock slates.

Salt Marl may have touched autochthon.

From a consideration of the above section, it is clear that a deposit of Salt Marl of Ranikot age might touch the floor of old slate rocks upon which the Salt Range and Kala Chitta rocks were deposited. The Giumal Spiti shale unit and the Kioto limestone are localised deposits which probably do not extend far south of the Kala Chitta. On the other hand, the Salt Range group from Lower Trias to Purple Sandstone are also deposits of localised character, which thin and die out somewhere north of the Salt Range. It is quite possible then that somewhere in the Potwar, the Ranikot Salt Marl was in actual contact with the floor of old slates upon which the *nappe* of Kala Chitta and Salt Range rocks moved. If that were so, it would probably result in the Salt Marl acting as a lubricant, just as the salt beds of the Jura have acted.[1] The presence of the Salt Marl separating the Tertiary suite of rocks from the floor of pre-Cambrian slates would enable the *nappe* to move southwards, without the intense folding that characterises the Kala Chitta. Oversliding has taken the place of close folding. It may also be assumed that the Salt Marl would be extruded underneath the *nappe* and along the floor of old pre-Cambrian rocks, so as to outcrop as it now does beneath the Purple Sandstone.

In most text-books a well-known section by Bailey Willis[2] shows how an incompetent bed will thicken out by the compressional

[1] *See* L. W. Collet, 'The Structure of the Alps', p. 139, and Fig. 39, (1927).

[2] *See* Bailey Willis in *13th Annual Report of U. S. Geol. Surv.*, II, pp. 211-283, (1893). E. Haug: 'Traité de Géologie', Vol. I, p. 215, Fig. 76, (1911); C. K. Leith, 'Structural Geology' p. 81, Fig. 34, (1923).

movements of a *nappe* of competent rocks overriding it, the thickening occurring near the line of emergence of the thrust-plane of the *nappe*. In a somewhat similar manner, it may be supposed that the Salt Marl was forced by the overcrawl of the overlying competent rocks to be extruded under pressure all along the foot of the Salt Range along the line of thrust.

Heaping up of Marl in direction of thrust.

Extrusion of Marl under the *nappe*

The whole process may be connected with a slow northward drift of Gondwanaland, and the undercrawl of the mass of *sial* under the deposits of the Tethys.

The extrusion of the Salt Marl beneath the Purple Sandstone does not appear to constitute a serious difficulty, if it is remembered that the Salt Range suite of rocks from the Purple Sandstone upwards are not, until the Laki is reached, continuous sheets extending to the Kala Chitta, but thin out and disappear to the north. The Salt Marl, if in contact with the floor of older rocks, would probably, during extrusion, move along the line of junction of the old pre-Cambrian floor and the Palæozoic or newer rocks above, since it is upon this floor apparently that the thrust-plane underlying the *nappe* developed. In Plate 18 a diagrammatic section is given in illustration of the above theory of the origin of the Salt Marl. The date of the extrusion must be placed very late, perhaps in Upper Siwalik to Sub-Recent times, and it may be noted that, while the Salt Marl *in its original state* has been assumed to be of Ranikot age, the date of its extrusion and attainment of its present position is very much later.

Of previous sections in this area may be mentioned two general sections; (1) that of W. Waagen, facing page 122 of *Rec. Geol. Surv. Ind.*, XVII, (1884); and (2) that by J. M. Weller in *Journal of Geology*, XXXVI, p. 366, (1928). Besides these two general sections, mention has already been made above of those through the Potwar by G. E. Pilgrim and those in the Kala Chitta and Potwar by Sir Edwin Pascoe and E. H. Pinfold.

The present section may perhaps claim to show some novel features; these are the *décollement* of the Kala Chitta, the theory that a *nappe* exists extending from the Kala Chitta through the Potwar area to the Salt Range, the dying out of the Giumal and Kioto deposits southwards, and likewise the dying out of the Salt Range formations northwards. It is not possible in so generalised a section to show the attenuation in the south of the later Tertiary

stages, but the theory that the Ferruginous Pisolite is an attenuated representative of a buried deposit of Salt Marl in the Potwar is indicated in the section. It is shown how this supposed deposit might have touched the autochthon, and thus have become intruded along the thrust-plane under the *nappe.*

The section is admittedly theoretical, and cannot be proved, although it appears to me to contain a probable explanation of the structure.

In the preparation of this chapter, I have, as may be readily seen, made free use of the work of previous observers. I have, I think, given full references in footnotes to such papers as I have used. The discovery by Mr. E. R. Gee of fossils in the Salt Marl, which proved to be of Ranikot age, is one of the main props of my theory, notwithstanding that Mr. Gee is unable to accept the view that the salt is intrusive and not *in situ.* It has always struck me as extraordinary that so undisturbed an area as the Potwar geosyncline should lie between the highly folded Kala Chitta and the thrust-faulted Salt Range. I have for years thought it probable that the *nappe* of the Salt Range continued northwards, so as to include the Kala Chitta, but have hitherto been unable to formulate a theory to account for the structure. I may, also mention that the work of Col. L. M. Davies, and the illuminating paper written by him in collaboration with Mr. D. N. Wadia have been of the greatest service to me. Finally I may record my indebtedness to Prof. Collet's book 'The Structure of the Alps', and especially the section in Fig. 39 of that book.

CHAPTER VIII.

ECONOMIC GEOLOGY OF THE ATTOCK DISTRICT.

Petroleum.

No fresh oilfields have been discovered since Sir E. H. Pascoe wrote his memoir on Petroleum in the Punjab.[1] The Khaur oil-field has been a steady producer from 1922 to 1929, the annual figures of production being—

Year.	Production in gallons.
1919	114,330
1920	51,492
1921	60,236
1922	7,362,315
1923	11,805,010
1924	11,383,440
1925	8,047,200
1926	6,230,320
1927	10,667,600
1928	12,254,160
1929	19,208,880
1930	7,662,200

In 1930, a fall of over 60 per cent. in the production of the Khaur field occurred; this was due to two factors, namely that no important new supply was obtained from sands down to 4,200 feet, whilst none of five deep wells being sunk to the 4,600 and 4,800 horizons had yet reached its objective.[2]

Drilling is proceeding in the Dhulian anticline, but the producing stage has not yet been reached.

In the Chharat anticline, the Lower Chharats and the passage beds between the Laki or Hill Limestone and the Chharats are known to be petroliferous. E. S. Pinfold[3] inclines to the opinion that the petroleum of the various seepages in the district is derived from this horizon. The petroleum of Khaur he regards as having

[1] *Mem. Geol. Surv. Ind.*, XL, Pt. 3, (1930).
[2] *Rec. Geol. Surv. Ind.*, LXV, p. 347, (1931).
[3] *Journ. As. Soc. Beng.*, N. S., XIV, p. clxxiii, (1918).

migrated into its present position in the Murree rocks from this Chharat horizon. He does not account for the seepages at Chak Dalla described by Sir Edwin Pascoe. These seepages occur in the Laki or Hill Limestone and in the Giumals. Sir Edwin thinks that the oil is either derived from one of the softer bands of concretionary limestone and shale in the Lakis, or from some buried Chharats below. This last view was advocated by E. S. Pinfold (verbal communication), who points to the bottle-shaped synclinal structure, in which some Chharats might be concealed.

It is not, however, necessary to assume that the only petroliferous horizon is the Lower Chharats and the passage beds. The Salt Marl is undoubtedly bituminous, and if we accept the suggestion put forward in preceding chapters that the Salt Marl is of Ranikot age and underlies the Potwar Lakis, it is possible that there may also be petroleum-bearing horizons below the Chharats, and the Laki limestone.

Pinfold would also refer the Salt Range seepages at Sadhewali, Mardwal, and Khabakki [1] to the Chharat horizon, but we have seen that the Chharats attenuate out in the Salt Range, and it seems more reasonable to suppose that the oil is seeping through the Laki limestone from a horizon immediately beneath.

Since Sir Edwin Pascoe and E. S. Pinfold wrote upon the oil of Attock and neighbouring districts, an important boring was put down at Jhatla, a village 8½ miles south by west of Talagang. The boring was situated 2¼ miles W.N.W. of the village, and the full record was published with the permission of the Whitehall Petroleum Company, by R. van V. Anderson, whose paper on the northern Punjab has so often been quoted in previous chapters. The hole was carried down to a depth of 6,007 feet; the base of the Middle Siwalik (Nagri stage) was found at 1,107 feet; the base of the Chinjis was at 3,914 feet; the base of the Kamlial-Murree series was at 5,925 feet. The well was continued downwards through 82 feet of Eocene beds rather more like the Chharats or passage beds than the Laki or Hill Limestone. In these Eocene beds, traces of petroleum were found, some rock specimens had an odour of petroleum and there was a dry oil residue impregnating joint planes and some of the beds. The boring was unsuccessful.

[1] *See* Pascoe, *op. cit.*, p. 436.

A paper by H. M. Lahiri[1] describes the anticlinal dome structure in the Murree series at Mari village $6\frac{1}{2}$ miles north of Jand, and discusses the prospects of oil.

It is not perhaps necessary for me to recapitulate the history of the searches made since the days of Fenner and Lyman for petroleum in the Attock district. Reference may be made to the above quoted papers by Sir Edwin Pascoe and E. S. Pinfold. The above remarks are intended to be supplementary to what has already been written. I have nothing to add to the opinions expressed by these authorities, except the suggestion already put forward that the Salt Marl may underlie the Laki limestone in the Potwar, and may be petroliferous. This assumption is hardly likely to modify seriously our estimates of the chances of finding petroleum in the areas discussed by Pascoe and Pinfold, except perhaps in the case of the Khair-i-Murat fold. This fold is, however, highly compressed with a faulted overthrow, and structurally is very far from being an ideal anticlinal reservoir, even supposing that the Salt Marl in Ranikot times extended as far north of the Soan as this fold lies.

The Joya-Mair dome fold described by D. N. Wadia[2] lies in the country east of the area shown in the map accompanying this memoir. Its prospects as a possible oilfield are discussed in the paper quoted.

Cement Manufacture.

At the eastern termination of the Hasan Abdal hill, in the village area of Wah, the Punjab Portland Cement Co. Ltd. have erected a factory for the manufacture of Portland Cement. The raw materials used are Laki limestone from the Hasan Abdal hill showing on analysis up to 98 per cent. of calcium carbonate, alluvial clay which is dug up close to the works, and gypsum, which comes from Khewra in the Salt Range. There is a water purification plant for treating the water obtained from tube wells, also limestone crushers, mixers, slurry tanks, grinders, etc. There are two rotary kilns each 6 feet in diameter and about 175 feet long. The clinker obtained is ground in ball mills to a high degree of fineness. The output is over 5,000 tons per month.

[1] *Rec. Geol. Surv. Ind.*, LXIII, p. 279, (1930).

[2] *Rec. Geol. Surv. Ind.*, LXI, p. 358, (1929).

Water Questions.

With the development of the country, the increase of population, and increased pressure on the land, water problems are coming more and more to the fore.

The low-level alluvium contains abundant water; in the high-level alluvium, water is found provided the alluvium is sufficiently deep and the adjacent ground not ravined by stream-beds. The well in the Rest House compound at Basal is in the high level alluvium, and yields a plentiful supply of good water.

At Jand, a deposit of unsorted material and sands (probably due to the catastrophic flooding which brought the erratic blocks to their present position) rests upon vertical or steeply dipping Murree rocks. These rocks act as an impervious base, and abundant water is found in the lower levels of the capping of sand and unsorted material. There are many wells and springs at Jand, which are derived from these sands.

The conditions at Jand illustrate an obvious fact, but one which has been often neglected by water experts, *viz.*, that where the strata are vertical or steep, and consist of alternate beds of impervious clay and pervious sandstone, a well, driven down in a bed of sandstone, dipping vertically, has two impervious walls of clay on either side, and therefore can only derive supplies of water from the particular bed of sandstone in which it is driven. So greatly is the supply area thus diminished that the consequence is, in hard and not too porous sandstones like those of the Murrees, only damp sandstone is found and the well is practically a dry hole or has no water to speak of. It is, therefore, inadvisable to drill in the Murree series in the isoclinal and fault belt where the dips are steep or vertical. In Fatehjang for instance, where the North-Western Railway are testing for water, I should be surprised if a supply was found in the Murree series.

In the Rawalpindi basin, water is found in the alluvium, but a drilled well which pierced the alluvium and entered the steeply dipping Murrees showed no addition to the water already obtained from the alluvium. This well was drilled by the North-Western Railway on the western ridge in the old Workshop compound.

For this reason, tube wells would be unsuccessful in the country between Pindi Gheb and Jand, if drilled in the rocks underlying the alluvium, unless they were located in geologically favourable ground

such as the undestroyed synclines which lie between the crushed anticlines of the fault belt. The same remarks apply to the Siwaliks where they are steeply dipping.

In the Soan geosyncline, the Siwaliks are horizontal or gently dipping. Wells can obtain water over this tract and springs are common, as, for instance, round Kot Sarang. Tube wells should find water; such wells have been successful near Chhab.

In the drilled well at Jhatla, water was found at 42 feet, 160 feet, 370 feet, and 850 feet. The water was artesian with a combined flow of about 600 gallons per hour. At 3,658 ft. a flow of water, at first over 4,000 gallons per hour, declining in two days to 400 gallons per hour, was met. Other flows were found at 3,841 ft. and 4,350 ft.

Both in the Salt Range and in the Kala Chitta, the Laki limestone is a source of vigorous springs. Similar springs occur at the foot of the Hasan Abdal hill. At Kallar Kahar in the Salt Range, the springs are charged with sulphuretted hydrogen. In the Hasan Abdal hill, it is impossible to suppose that the springs of abundant perennial water derived their supply from so small a catchment area as the Hasan Abdal hill. They evidently travel from some distant source, possibly the Himalayan foothills to the north.

Coal.

Worthless seams of coaly shale with strings of coal occur in the Laki limestone near Surg, eight miles south-west of Campbellpur. There is no coal of economic value in the district.

Building Stones.

The Middle and Lower Siwalik sandstones are usually too soft for building purposes, but are used by the villagers with mud to build the walls of their houses. The Murree sandstones are hard enough if selected. The Laki and Kioto limestones make good building stones, while the shell limestone of the Giumal–Spiti shale unit is rather an ornamental stone, and has been used for making vessels, both in recent times and in the days when Taxila flourished. The steps of the Badshahi mosque at Lahore are made of rock of this age, but not necessarily from occurrences in the Attock district.

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MGIPC—M—VIII-4-17—22-8-33—700.